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Hazardous Waste Disposal Program 8th Monthly Report

TRW Systems Group

Prepared For
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September 9, 1972

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During this month the effort towards determing waste locations and quantities was continued. Preliminary estimates for major classes of hazardous waste materials designated as candidates for National Disposal Sites were prepared in recognition of the early requirements of the Feasibility Study. The emphasis of this effort was placed on the inorganic compounds and pesticides, data for the organic compounds being much less available. Data has been tabulated for the pesticides (herbicides, insecticides and fungicides), arsenic and its compounds, mercury and its compounds, cadmium and its compounds, and lead and its compounds. For the most part these estimates are incomplete and should, therefore, be assigned a large uncertainty, i.e., a factor of 1/2 on the low side and as high as 3 on the high side.

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HAZARDOUS WASTE DISPOSAL PROGRAM

EIGHTH MONTHLY REPORT

CONTRACT 68-03-0089

Prepared for
the
Environmental Protection Agency

9 September 1972

TRW
SYSTEMS GROUP
ONE SPACE PARK • REDONDO BEACH, CALIFORNIA

21485-6008-T0-00

HAZARDOUS WASTE DISPOSAL PROGRAM

EIGHTH MONTHLY REPORT

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1. INTRODUCTION

Under the requirements of Section 212 of Public Law 91-512, The Office of Solid Waste Programs of the Environmental Protection Agency is in part required to prepare "a comprehensive report and plan for the creation of a system of national disposal sites for the storage and disposal of hazardous wastes, including radioactive, toxic chemical, biological, and other wastes which may endanger public health or welfare. Such a report shall include: 1) a list of materials which should be subject to disposal in any such site; 2) current methods of disposal of such materials; 3) recommended methods of reduction, neutralization, recovery, or disposal of such materials.

Contract 68-03-0089 is the second in a series of EPA projects which are designed to provide the information required in the report to Congress. The principle objective of the current program is to define and evaluate the waste management techniques and policies currently utilized for a specified set of hazardous wastes. Waste management techniques which will be evaluated include those for storage, handling, transport, neutralization, detoxification, reuse, and disposal. Other aspects of the program include description of possible new techniques for management of hazardous wastes, proof-of-principal experimentation to determine the effectiveness of techniques for which insufficient data is available for adequate evaluation, and planning of research programs necessary for developing new procedures and processes for treating hazardous wastes for which adequate techniques do not currently exist.

The eighth monthly technical report summarizes the work performed by TRW for EPA from August 1, 1972 to August 31, 1972 under Contract 68-03-0089.

2. PROGRAM ACCOMPLISHMENTS

The program is divided into seven major tasks consisting of:

- Defining Adequate Waste Management. Toxicity information and toxicological standards on each hazardous material contained in lists supplied by the Solid Waste Research Office will be reviewed. Other factors (such as flammability or explosive potential) which affect the waste management process will be investigated where applicable. Acceptable criteria in terms of impact on mankind and the environment for each of the waste management steps (handling, storage, transportation, disposal, etc.) shall be defined.

- Evaluating Presently Employed Waste Management Techniques or Policies and Making Recommendations as to Adequacy. The existing techniques for waste management of each hazardous material (supplied as in Task 1) will be assessed in relation to the criteria defined in the first task. Adequate techniques shall be recommended in order of preference and any required state-of-the-art modifications prescribed. Techniques which are applicable to national disposal sites will be specified.

- Performing Field Surveys and Verification Experiments on Existing Management Procedures. In cases where adequate information to determine the effectiveness of a particular waste management technique are not available, special field surveys or verification experiments will be performed. Results of those studies will be recycled to Task 2 to complete the evaluation of the particular hazardous waste material.

- Defining, Planning and Outlining Research Programs Where Necessary for Elimination of Hazards. Where no acceptable waste management techniques currently exist for a particular hazardous waste material, efforts will be made to innovate new approaches and the necessary research and/or demonstration programs will be planned and outlined. Prioritization of the programs in terms of importance of the problem and probability of success will be accomplished.

- Conducting Proof-of-Principle Experimentation on the Most Promising Concepts. Within the constraints of schedule and budget, proof-of-principle type experimentation will be conducted on the most promising but unproven concepts.

- Determining Waste Forms. Additional information on the hazardous waste materials designated under the earlier tasks as candidates for National Disposal Sites will be collected, analyzed and presented as an integral part of this program. This information will include the forms in which the wastes are found, their location, and the quantities of waste material generated.
- Correlating Total Program Effort. The program is directed to provide inputs to a final report which will: 1) summarize the best available waste management techniques for each material; 2) list on a prioritized basis those techniques to be included at possible National Disposal Sites; and 3) indicate major gaps in current hazardous waste management technology and provide a comprehensive, prioritized research and development plan for obtaining the required technology.

During August effort was concentrated primarily on Tasks 1, 2 and 6 of the program. The specific areas addressed were: (1) Profile Reports for both chemical and nuclear hazardous wastes, (2) determination of the quantities and locations of various hazardous wastes, and (3) determination of the forms of hazardous wastes. These efforts are discussed in the following sections.

2.1 PROFILE REPORTS

During the last month, Profile Reports for 34 category 1 and 27 category 2 chemical compounds were completed. Reports for the following hazardous chemical materials were prepared and are presented in Appendix A.

Category 1

80 - Cacodylic Acid
234 - Lead Acetate
237 - Lead Acarbonate
238 - Lead Chlorite
240 - Lead Nitrate
241 - Lead Nitrite
252 - Manganese Sulfate
258 - Organic Mercury
333 - Phosphorus Trichloride
334 - Phosphorus Pentachloride
335 - Phosphorus Pentasulfide
336 - Phosphorus Trichloride
338 - Picric Acid
382 - Sodium Cacodylate
423 - Tear Gas, Irritant
430 - Thallium
431 - Thallium Sulfate
501 - Manganese Chloride
517 - Copper Acetylide
519 - Cyanuric Triazide
520 - Primers & Detonators
521 - Dipentaerythritol-Hexanitrate
523 - Gelatinized Nitrocellulose
524 - Glycerolmonolactate Trinitrate
525 - Glycol Dinitrate
529 - Lead Azide
531 - Lead Styphnate
532 - Mannitol Hexanitrate
533 - Mercuric Fulminate
534 - Nitrocellucose
535 - Polyvinyl Nitrate
536 - Potassium Dinitrobenzburoxan
537 - Silver Acetylide
538 - Silver Azide

Category 2

100 - Carbon Tetrachloride
104 - Chloral Hydrate
107 - Chloracetophenone
108 - Chlorbenzene
109 - Chloroform
140 - p-Dichlorobenzene
141 - o-Dichlorobenzene
142 - Dichlorofluoromethane
143 - Dichloroethyl Ether
145 - 1,2-Dichloropropane
146 - 1,3-Dichloropropene
147 - Dichlorotetrafluoroethane
171 - Epichlorin
180 - Ethyl Chloride
185 - Ethylene Dichloride
269 - Methyl Chloroformate
325 - Perchlorethylene
340 - Polyvinyl Chloride
424 - Tetrachloroethane
436 - Trichlorobenzene
437 - Trichloroethane
438 - Trichloroethylene
439 - Trichlorofluoromethane
450 - Vinyl Chloride
497 - Hexachlorophene

Profile Reports on eight radioactive waste compounds were completed during August. Those completed during August are listed below and the first draft reports are presented in Appendix B.

Carbon - 14
Cobalt - 60
Iridium - 192
Radium - 226
Iodine - 129
Iodine - 131
Kryton - 85
Xenon - 133

Although it was anticipated that all Category 1 Profile Reports would be contained in these first eighth monthly reports, the determination of waste quantities was considered of sufficient importance to justify the reassignment of personnel who were expected to finish the Category 1 reports. There are, therefore, 27 chemical hazardous waste Profile Reports remaining to be written:

16 - Aluminum Fluoride
60 - Boric Acid
64 - Bromic Acid
121 - Copper Nitrate
122 - Copper Sulfate
242 - Lead Oxide
243 - Lewisite
245 - Magnesium Arsenite
289 - Nickel
324 - Perchloric Acid
322 - Pentachlorophenol
332 - Phosphorus, Wh. or Yel.

2.2 DETERMINATION OF WASTE QUANTITIES AND LOCATIONS

During August the effort towards determining waste locations and quantities was continued. Preliminary estimates for major classes of hazardous waste materials designated as candidates for National Disposal Sites were prepared in recognition of the early requirements of the Feasibility Study. The emphasis of this effort was placed on the inorganic compounds and pesticides, data for the organic compounds being much less available. Data has been tabulated (Appendix C) for the pesticides (herbicides, insecticides and fungicides), arsenic and its compounds, mercury and its compounds, cadmium and its compounds, and lead and its compounds. For the most part these estimates are incomplete and should, therefore, be assigned a large uncertainty, i.e., a factor of 1/2 on the low side and as high as 3 on the high side.

In preparing these tables quantitative information from the Booz-Allen final report was included only where TRW had additional information, therefore, the Appendix C tables should be supplemented by the Booz-Allen tables (primarily III-6, III-9, and III-10) in determining quantities of wastes other than those listed. It is anticipated that further information will be included in monthly reports as it can be summarized.

2.3 IDENTIFICATION OF WASTE FORMS

During August a subcontract was negotiated with Rollins-Purle, Inc. to provide an interpretation of information from their files on the chemical analysis (composition) of the over 3,600 industrial waste streams which they treat or have been asked to treat. The results of this report were received and reviewed on September 7, 1972 and will provide the basis for upgrading the tables in Appendix C and for providing additional tables.

349 - Potassium Permanganate
470 - Barium Fluoride
478 - Beryllium Fluoride
514 - Benzoyl Peroxide
515 - 1,2,4-Butanetriol Trinitrate (BTTN)
516 - Chlorates W/red Phosphorus
518 - Copper Chlorotetrazole
522 - Dipentaerythritol - Hexanitrate
526 - Gold Fulminate
527 - Hydrazine Azide/Hydrazine
530 - Lead 2,4 Dinitroresorcinate
539 - Silver Styphnate
540 - Silver Tetrazene
541 - Smokeless Gun Powder
542 - Tetrazene

There are also six radioactive wastes profile reports remaining:

^{3}H - Tritium
Sodium - 14
Titanium - 44
Iron - 55
Nickel - 63
Tantalum - 182

It is anticipated that these will be included in the ninth monthly together with the scheduled Category 2 and 3 Profile Reports. A table briefly summarizing the Profile Report conclusions and indicating which monthly report contains a given report is presented in Appendix D.

3. WORK PLANNED FOR SEPTEMBER

As described above, the Category 1 Profile Reports will be completed during September as will many of the Category 2 and Category 3 organic and inorganic material reports. The effort on waste forms identification will continue as mentioned above with particular emphasis on utilizing the information obtained from Rollins-Purle, Inc. A coordination meeting with other contractors involved in the overall Hazardous Waste Disposal-National Disposal Site effort is planned for September 20, 1972.

APPENDIX A - PROFILE REPORTS

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PROFILE REPORT

Cacodylic Acid (80) and Sodium Cacodylate (382)

Cacodylic acid and its sodium salt are poisonous compounds that are used in agriculture as post emergent, leaf contact, weed killers and defoliants. The acid is also called dimethylarsinic acid; its formula being $(CH_3)_2$ AsOOH. Either the acid or the salt is used depending on the pH of the solution used for a specific application. For purposes of this Profile Report, the two compounds will be referred to as the cacodylates.

These compounds are normally produced and applied as solutions. The estimated annual production is about 1,200,000 gallons.[2215] These solutions generally contain 2 to 3 lb of cacodylates per gallon of solution. The Ansul Chemical Company of Marinette, Wisconsin is responsible for about 80 percent of the cacodylate production. The Vineland Chemical Company produces much of the remaining 20 percent. The cacodylates have EPA registered uses in non-bearing citrus groves, utility rights of way, ornamental turf control under the trees and shrubs, and around industrial sites. Recent or soon to be added registrations include uses in bearing citrus groves and as defoliating agents in cotton fields.[2021,2215] Residues from the fallen leaves or material misdirected to the ground from spraying become tightly bound to soil particles in a form of irreversible adsorption. Representatives of Ansul Chemical Company indicated that studies have confirmed no residual plant toxicity in the soil because these compounds cannot be leached from the soil or taken up by plant root systems. As an example, they cited the Scott Lawn products people who, a number of years ago, marketed a cacodylate base compound which they called "Erase". Erase was applied to ornamental lawn areas as a contact herbicide, and in three or four days the lawn died. A new seeding could then be made immediately with no harmful effects on the new lawn.

Ansul representatives indicated that use of the cacodylates is heaviest in Texas with smaller amounts being consumed in Arizona and

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California. Consumption in the rest of the United States is considered commercially insignificant.[2215]

Manufacture of Cacodylates

The commercial production of cacodylic acid is a 3-step process. Arsenic trioxide is reacted with sodium hydroxide to yield sodium arsenite. Methyl chloride is added to produce methanearsonic acid, $CH_3AsO(OH)_2$. The mixture is then reduced with SO_2 and methylated to recover the dimethylarsinic acid.[2215] There is no liquid effluent from this process as all the liquid streams are recycled for reuse. A number of multiple effect evaporators are employed in the solution recycling systems. The process does, however, create a solid waste which is a mixture of sodium chloride and sodium sulfate containing 1 to 1-1/2 percent cacodylate contaminants. The rate at which this material is produced is not known but it is known that 60,000,000 lb are currently being stored in concrete vaults in the Marinette, Wisconsin area. There are currently no plans for the material other than to store it indefinitely.[2214]

Market Trends for Cacodylate Compounds

Cacodylic acid production was heavier in the early and mid-sixties when the Army was buying large amounts of it under the general description of defoliants. It was used extensively in Vietnam for the destruction of rice fields, now a discontinued practice. Production dropped significantly when Army purchases ceased but the trend is again toward increased consumption of the cacodylates because of new EPA registrations for use of cacodylates on cotton and bearing citrus groves.

2. TOXICOLOGY

Human Toxicity

Organo-arsenic compounds are highly toxic materials and are very dangerous even in low concentrations.[0766] The American Conference of

Governmental Hygienists has recommended a Threshold Limit Value (TLV) of 0.5 milligrams per cubic meter of air for all arsenic compounds.[0225] This value represents the conditions to which nearly all workers may be repeatedly exposed on an 8-hr period without adverse effect.

Acute arsenic poisoning from ingestion results in corrosive irritation of the stomach and intestines with accompanying nausea, vomiting and diarrhea. In severe cases, collapse and shock can occur with a weak, rapid pulse, cold sweats, coma or death. The diagnosis of latent, chronic arsenic poisoning is difficult since the condition manifests itself with many different and unpredictable symptoms. Included are disturbances of the digestive tract, liver damage resulting in jaundice, blood and kidney disturbances and a variety of skin abnormalities.[0766]

Toxicity Towards Plant and Animal Life

Since these compounds are used as herbicides and defoliants, it is reasonable to believe that they are harmful to terrestial plant life in general. Arsenic concentrations of 2 to 4 ppm have been found to not interfere with the self purification of streams, however, fish display harmful effects at about 15 ppm.[1752] It is reasonable to assume that toxic levels for terrestial animal life are about the same as levels determined for humans.

3. OTHER HAZARDS

The cacodylates do not exhibit any explosive, flammable, or volatile properties, nor do they present any other hazards.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage and Transportation

The cacodylate herbicides because of their toxicities require special consideration for storage, handling, transportation and disposal.

Storage areas for these compounds should be isolated from locations where food and animal feed are stored. The waste materials should be stored in the type of containers originally used by the manufacturer. Cacodylate solutions are packed and shipped by Ansul Chemical Company in 30-gal, phenolic-lined metal drums, 5-gal metal pails and 1-gal high density polyethylene bottles packed four to a case. Ansul also packs a solid product in a polyethylene lined 100-lb fiber drum.[2215]

Protective clothing, goggles, gloves and dust filtering respirators are recommended for unloading or otherwise handling these herbicides. Similar precautions are recommended for handling any liquid solutions. Spills of the solid materials should be cleaned up using a vacuum cleaner after a fine spray of water has been laid down to prevent dust. The liquid compounds or formulations should be handled in an area such that if they are spilled they can be contained for easy clean up or transfer to a sump where they will not create a hazard.

The cacodylates are classified as Class B poisons. The regulations of DOT and ICC should be followed when shipping, storing, or otherwise handling the cacodylates.

Disposal/Reuse of Cacodylates

The wholesale disposal of these materials into the air, water or soil must be considered completely unacceptable considering their high toxicities. The U.S. Public Health Service has established a maximum of 0.05 mg/l arsenic content (50 ppb) for drinking water if no other drinking water is available. The ideal maximum is 0.01 mg/l (10 ppb). The aqueous discharges containing 0.01 mg As per liter are considered acceptable for open waterways. There are no official acceptable levels of discharge into the air, but an ambient air level of 0.005 milligrams per cubic meter is recommended.

The cacodylates do not cause soil sterility or adverse plant effects when found in the soil; nevertheless disposal of them by land spreading is not recommended because intentional loading of soil with material not naturally found there is environmentally unacceptable when easier, cheaper options are available.

There are channels by which unused and unopened containers of cacodylate compounds can be returned to the manufacturer for resale.[2215] Representatives of Ansul also indicated that they would accept contaminated or otherwise unwanted material for recycling provided that a process to remove contaminants was technically and economically feasible.

5. EVALUATION OF WASTE MANAGEMENT TECHNIQUES

The cacodylates are not expected to occur as waste products in a reasonably pure or concentrated form. The only identified cacodylate wastes were from the salt by-products from cacodylate manufacturing and from that found in the soil. A feasible disposal process for the contaminated salt by-product has not been identified. The soil borne cacodylates do not present a hazard since they are bound to the soil and are not leachable or transportable to plant root systems. The waste management options for the cacodylates are presented below.

Option No.1 - Recycle/Reuse

Representatives of Ansul Chemical Co. have stipulated the conditions under which the usable cacodylates can be returned to them for reprocessing or resale.[2215] They will accept unwanted stocks for resale without any reprocessing if the batch had originally been made by Ansul and if the materials were in their original unopened containers. This is a completely adequate waste management technique for these materials if they are in a concentrated form.

Option No.2 - Long Term Storage

Storage of cacodylates until they can be used or reprocessed is a satisfactory waste management option. These materials are stable compounds and require the minimal storage precautions needed for any toxic material. Storage in the original containers is recommended but they should be periodically checked for corrosion or breakage of the containers. Bulk quantities can be stored in concrete vaults or weatherproof bins.

Option No. 3 - Landfill

Disposing of concentrated cacodylate compounds suitably containerized in stable landfills is adequate but is not recommended unless the materials cannot be used. Should the stocks of any unusable waste cacodylates become unmanageably large, landfill or disposal of other sites such as abandoned quarries or mines could be used.

Summary of Available Waste Management Techniques

The available waste management techniques are as follows:

Option	Remarks
Long term storage until used	Best method if stocks are small or future use is projected.
Recycle/Reuse	Returned stocks currently resold by manufacturers.
Stable landfill	Should replace long term storage only if wastes become unmanageable.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Processes for specifically treating cacodylate wastes should not be included in a National Disposal Site because: (1) they have a current commercial agricultural usefulness; (2) soil residues have been found to be non-toxic to plants and difficult to remove from the soils; and (3) no process is currently known which can detoxify organo arsenic compounds. 2173 The site still should be chartered to accept all forms of arsenic compounds, waste cacodylate mixtures included, that are transported to it. Once at the site it is believed that the best management option is long term storage until they are consumed for a safe, useful purpose, or if unusable, permanently committed to storage or non-retrievable landfill. The available waste management options for National Disposal Sites are listed in order of decreasing preference.

	Option	Remarks
Best:	Long term storage	Best current method.
	Landfill	Site must be safe and should be used only if stored stocks become too large.

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Cacodylic Acid

IUC Name Dimethylarsinic acid

Common Names Alkargen

Structural Formula

$(CH_3)_2AsO_2H$

Molecular Wt. 138.00(1) Melting Pt. 200 C(1) Boiling Pt. ____

Density (Condensed) ____ @ ____ ____ Density (gas) ____ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

____ @ ____ ____ @ ____ ____ @ ____

Flash Point ____ Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water very soluble Hot Water ____ Ethanol very soluble

Others: ____

Acid, Base Properties ____

Highly Reactive with ____

Compatible with ____

Shipped in ____

ICC Classification Poison B, poison label, 200 lbs Coast Guard Classification Poison B, poison label

Comments essentially non-irritating to skin,(2) Acute oral LD_{50} for rats 1,350 mg/kg(2)

References (1) 1570
(2) 1784

382

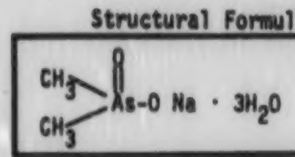
HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Sodium cacodylate

IUC Name Sodium dimethylarsinate

Common Names

Structural Formula



$(CH_3)_2As(=O){-}O\,Na \cdot 3H_2O$

Molecular Wt. 314.21(1)

Melting Pt. $-H_2O$ 120 C(1)

Boiling Pt.

Density (Condensed) @

Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 83 g/100 g(2) decomposes(1)

Hot Water decomposes(1)

Ethanol

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Poison B, poison label. 200 lbs(3)

Coast Guard Classification Poison B, Poison label(3)

Comments Relatively non irritating to skin and eyes(2)

References (1) 1570
(2) 1784
(3) 0766

PROFILE REPORT

ALIPHATIC HALOGENATED HYDROCARBONS:

Carbon Tetrachloride (100), Chloral Hydrate (104), Chloroform (109), Dichlorofluoromethane (142), Dichloroethyl Ether (143), 1,2-Dichloropropane (145,363) 1,3-Dichloropropene,(146), Dichlorotetrafluoroethane (147), Epichlorin (171), Ethyl Chloride (180), Ethylene Dichloride (185), Methyl Chloroformate (269), Perchlorethylene (325), Polyvinyl Chloride (340), Tetrachloroethane (424), Trichloroethane (437), Trichloroethylene (438), Trichlorofluoromethane (439), Vinyl Chloride (450)

AROMATIC HALOGENATED HYDROCARBONS:

Chloracetophenone (107), Chlorbenzene (Chlorbenzol)(108), *o*-Dichlorobenzene (140,278), *p*-Dichlorobenzene (141), Trichlorobenzene (436), Hexachlorophene (497).

1. GENERAL

Introduction

The halogenated hydrocarbons treated in this report have all been selected as probable candidates for industrial disposal. These materials are similar in that most are commodity chemicals with relatively low toxicity, well-defined and safe methods of industrial handling and common methods of disposal. The halogenated hydrocarbons are, therefore discussed as a class in this report.

Manufacture

Most of this group of chemicals are produced by chlorination of the parent hydrocarbon by addition and/or substitution reactions. Addition of chlorine to a double bond (Equation 1) yields no side products and the selectivity is nearly 100 percent. By contrast, substitution (Equations 2 and 3)

(1) $R\text{-}CH{=}CH\text{-}R + Cl_2 \longrightarrow R\text{-}CHClCHCl\text{-}R$ addition

(2) $Ar\text{-}H + Cl_2 \longrightarrow Ar\text{-}Cl + HCl$ substitution

(3) $R\text{-}H + Cl_2 \longrightarrow R\text{-}Cl + HCl$ substitution

results in the formation of hydrogen chloride as a by-product and is normally less than 90 percent selective. The side products are usually isomers containing more or less chlorine than the desired product.[1655,1501] Several steps may be necessary to produce the desired compound in a series of addition and substitution reactions. The crude products can contain isomers, side products, hydrochloric acid, chlorine and varying amounts of chlorinated sludge. Thus all commercial processes have units for removing hydrochloric acid and chlorine and a final distillation is used to remove isomers and "heavy bottoms."

Vinyl chloride is made by pyrolysis of ethylene dichloride (or related technology) and the fluorochlorohydrocarbons are made from the corresponding chloro compounds by displacement of the required amount of chlorine by hydrofluoric acid in the presence of antimony pentachloride.[0534,1433,1501]

Uses

The fluorochlorohydrocarbons (Freons®) are used principally as refrigerants and aerosol propellants due to their chemical inertness, non-flammability, non-toxicity and almost total lack of allergenic reactions.[1433]

Chlorinated hydrocarbons have excellent solvent properties. By varying the basic hydrocarbon (usually methane, ethane, ethylene or benzene) and the amount of chlorine substitution, a wide range of solvent specificity and operating temperatures can be obtained. In addition, they are simple and relatively cheap to prepare and have a high degree of chemical stability. For these reasons, they are widely used as solvents for oils, fats, lacquers, resins, varnishes, extraction solvents for natural products, solvents for organic reactions, degreasers and dry cleaning agents.

The chlorinated hydrocarbons, because of their relatively low toxicity have also found use as soil fumigants (carbon tetrachloride, 1,3-dichloropropene, dichloroethylene, tetrachloroethane), insecticides (*o*- and *p*-dichlorobenzene, carbon tetrachloride, tetrachloroethylene, trichlorobenzene), disinfectants (hexachlorophene), and various medical and veterinary uses (chloral, ethyl chloride, carbon tetrachloride, chloroform, tetrachloroethylene, trichloroethylene) as well as food additives (ethylene dichloride, hexachlorophene).[1492,1506,2253]

Many of these compounds are used as starting materials in organic synthesis. Chloroform, carbon tetrachloride, perchloroethylene and others are used to make refrigerants, aerosols and propellants (Freons®).[1433,1506,1655] Chloral hydrate and chlorobenzene are used in the manufacture of DDT, ethyl chloride is used to make tetraethyl lead, ethylene dichloride is a precursor to vinyl chloride, chlorobenzene is used to manufacture phenol and aniline and methyl chloroformate is used in a variety of organic syntheses.[1492,1506]

The higher boiling chlorohydrocarbons, chlorobenzene, and *o*-dichlorobenzene are used as heat transfer media.[1492] Vinyl chloride is used to make polyvinyl chloride and epichlorohydrin is used in epoxy resins.[1492,1506]

Physical and Chemical Properties

The physical and chemical properties of the compounds discussed in this report are included in the attached worksheets.

2. TOXICOLOGY[0766,1433,1492,2253]

Chlorinated Aliphatic Hydrocarbons

The substitution of a chlorine atom for a hydrogen greatly increases the anaesthetic action of a member of the aliphatic hydrocarbon series. In addition,the chlorine derivative is usually less specific in its action and may affect other tissues of the body in addition to those of the central nervous system; in many cases, the chlorine derivative is quite toxic. For example, chloroform, in addition to its narcotic qualities, may cause liver, heart and kidney damage.

As a general rule, the unsaturated chlorine derivatives are highly narcotic but less toxic than the saturated derivatives, thus causing degenerative changes in the liver and kidneys less frequently. In the saturated group, the narcotic effect is enhanced with an increase in the number of chlorine atoms. However, there is less relationship between the number of chlorine atoms present and the toxicity of the compound.

In dealing with these chlorinated hydrocarbons, it must be remembered that a toxic action may result from repeated exposure to concentrations which are too low to produce a narcotic effect, and which consequently, are too low to give warning of danger. Individual susceptibility is also important when poisoning by this group of solvents is being considered. Certain workmen may be seriously affected by concentrations that seem to have no effect on fellow employees in the same exposure.

The chlorinated hydrocarbons are also irritants to the eyes and the mucous membranes. Repeated direct exposure to the skin may result in dermatitis and poses the additional danger of absorption through the skin.

The chlorofluorohydrocarbons have a very low level of toxicity and are almost completely non-allergenic. The primary danger associated with these materials is that very high concentrations cause narcosis and anaesthesia.

Chlorinated Aromatic Hydrocarbons

In most instances, it is difficult to predict the toxicity of these compounds. However, in the case of most aromatic chlorine compounds, their toxicity is usually no greater, and frequently less, than that of the corresponding aromatic hydrocarbons.

The Threshold Limit Values (TLV) and maximum allowable concentrations that have been established are:

1. Chlorinated Aliphatic Hydrocarbons	TLV		MAC
	ppm	mg/M³	ppm
Carbon Tetrachloride	10	65	25
Chloral Hydrate	N/A	N/A	N/A
Chloroform (Trichloromethane)	25	120	50
Dichlorofluoromethane (Freon 12)	1000	4950	1000
Dichloroethyl Ether	5	30	
1,2-Dichloropropane	75	350	75
1,3-Dichloropropene	N/A	N/A	N/A
Dichlorotetrafluoroethane (F 114)	1000	7000	
Epichlorohydrin	5	19	
Ethyl Chloride (Chloroethane) in Cyl.	1000	2600	1000
Ethylene Dichloride (Dichloroethylene)	50	200	50
Methyl Chloroformate	N/A	N/A	N/A
Perchloroethylene	100	670	
Polyvinyl Chloride	N/A	N/A	N/A
Tetrachloroethane	N/A	N/A	N/A

	TLV		MAC
	ppm	mg/M^3	ppm
1. Cont'd			
Trichloroethane	350	1900	500
Trichloroethylene	100	535	100
Trichlorofluoromethane	N/A	N/A	N/A
Vinyl Chloride	200	770	
2. Chlorinated Aromatic Hydrocarbons			
Chlorbenzene (Chlorbenzol)	75	350	75
o-Dichlorobenzene	50	300	50
p-Dichlorobenzene	75	456	75
Trichlorobenzene	N/A	N/A	N/A
Hexachlorophene (Methylene)	N/A	N/A	N/A

3. OTHER HAZARDS

All chloro-, chlorofluoro- and bromohydrocarbons, when heated to decomposition, give off noxious and highly toxic fumes. The fumes consist of the corresponding halo-acids, the free halogens and, in the case of chlorine containing compounds, phosgene.[0766,1492,1569] In addition, these compounds will also react, sometimes explosively, when they come into contact with the alkaline and alkaline earth metals, and may be very corrosive to aluminum, especially under abrasive conditions.[1569,2253] These compounds have a wide range of flammability and tendency to explode (noted in the respective worksheets); none are shock-sensitive or subject to detonation.

4. DEFINITION OF WASTE MANAGEMENT PRACTICES

Handling, Storage and Transportation

The halogenated hydrocarbons are all toxic to a certain extent by inhalation or skin contact. These materials should be handled in a well-ventilated area and protective clothing and respirators are recommended where necessary. In cases of accidental contact, all contaminated clothing should be removed instantly and the skin washed thoroughly with soap and water.[0096,1811,2253]

Storage of these materials should be in cool, dry, well-ventilated areas, away from acute fire hazards. Materials with low boiling points should be protected from excessive heat and against sudden rise in temperature.

These materials are shipped under a variety of U.S. Department of Transportation, Coast Guard and IATA regulations. Most regulations relate to the flammability and volatility of these compounds.[0018,2253,1569] Information on safe handling and use of these compounds can be found in the Chemical Data Sheets published by the Manufacturing Chemists Association,[1809,2254] standard reference sources of manufacturers' Technical Data Sheets.[2253]

Disposal/Re-use

Commercial operations that use chlorinated compounds for dry cleaning, degreasing and as solvents, usually have on-site reclaiming procedures that recycle the materials indefinitely.[2255,2256,2257] In most operations, there is a finite loss to the atmosphere and the materials must be constantly replenished. There is usually no provision for solvent exchange but there are commercial solvent reclaimers who will re-possess contaminated solvents.[2257,2258]

The fluorohydrocarbons are used indefinitely or until equipment failure results in their release into the atmosphere.[2261] The aerosol propellants are discharged directly into the air and are not recoverable.

In manufacture, recycling and reclaiming, there is a solid, semi-solid or liquid residue containing varying amounts of solvent and chlorinated and non-chlorinated materials. In the manufacture of ethylene dichloride/vinyl chloride, this sludge represents approximately 1 percent of the total raw materials used, or 50 to 70,000,000 lbs per year.[2259] Present practice is to dispose of this material by landfill.[2259,2260] It is not known whether the complete elmination of atmospheric losses resulting in indefinite recycling of solvents will generate a severe reclaiming problem.

The users of very large volume chemical intermediates (ethyl chloride, ethylene dichloride, vinyl chloride, chloroform, carbon tetrachloride, perchloroethylene, epichlorhydrin, etc.,) completely recycle any unused materials after a stripping/purification step.[0534,1501,2259,2260]

The halogenated products considered in this report do not usually come into contact with aqueous media during manufacture except in special cases. Therefore, the discharge of dilute aqueous waste streams is not a problem. In most cases, small amounts of dispersed halocarbons can be removed by settling and the small amounts dissolved may be removed by lagooning and slow evaporation.[0534,1501]

Recommended air and water standards are listed below. The air standard is .01 TLV and the water standard is .01 TLV by weight in 2 liters of water. No standards have been recommended for compounds for which TLV's have not been established.

Substance	Limit for Air (Man)		Limit for Water (Man)	Limit for Water (Fish)
	ppm	mg/M^3	ppm or mg/l	ppm or mg/l
Carbon tetrachloride	0.1	0.65	1.95	1 - 10
Chloral hydrate	-	-	-	-
Chloroform	0.25	1.2	6	0.1
Dichlorofluoromethane	10	49.5	247.5	
Dichloroethyl ether	0.05	0.30	1.5	1 - 10
1,2-Dichloropropane	0.75	3.5	17.5	1.5
1,3-Dichloropropene	-	-	-	4.0
Dichlorotetrafluoroethane	10	70	350	-
Epichlorohydrin	0.05	0.19	0.95	0.01 - 1.0
Ethyl chloride	10	26	130	10 - 100
Ethylene dichloride	0.5	2.0	10	1.5
Perchloroethylene	1.0	6.70	33.50	0.1 - 10
Trichloroethane	3.5	19	19	0.75
Trichloroethylene	1.0	5.35	26.75	5.5
Vinyl chloride	2.0	7.70	38.50	
Ethylene dibromide	-	-	-	-
Chlorobenzene	0.75	3.5	17.5	0.35
o-Dichlorobenzene	0.50	3.0	15.0	0.05
p-Dichlorobenzene	0.75	4.5	22.5	0.05
Trichlorobenzene	-	-	-	0.01 - 1.0

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Option No.1 - Recycling

The dry cleaning, refrigeration, degreasing and solvent extraction industries, as well as processors using halocarbons as raw materials, all recycle as much of their halocarbons as possible. For small users or companies with badly contaminated lots, commercial solvent reclaimers reprocess the materials for further use.[2255,2256,2257,2261]

Option No.2 - Incineration

Badly contaminated solvents that cannot be reclaimed, as well as chlorinated and non-chlorinated residues and sludges, can be disposed of by incineration. Some of the materials, especially those with high chlorine content may not support combustion by themselves, but can be burned if an auxiliary fuel is used. Care must be exercised to assure complete combustion to prevent the formation of phosgene. An acid scrubber is necessary to remove the halo acids produced. In this manner, both long- and short-term environment effects are eliminated at the source in one simple disposal step.

Option No.3 - Landfill of Residue and Sludges Obtained During Manufacture or Use

The total production of the major halocarbons exceeded 16 billion pounds in 1970. If one makes the conservative estimate that byproduct production of chlorine-containing residues and sludges is equivalent to 1 percent of production, at least 160 million pounds (80,000 tons) of unusable material must be disposed of each year. Presently, this material is collected by various commercial scavengers and landfilled, often in remote places.[1501,2259,2260] The dry cleaning, degreasing and solvent recovery industries as well as the industries that use halocarbons for raw materials also generate sludge or waste solids but with very much lower chlorine content. These wastes, especially the smaller amounts, are often landfilled locally.[2256]

Deposit by landfill of halogen-containing waste, especially those which are generated in the production of chlorinated hydrocarbons, presents a serious long-term environmental hazard to man, animals and fish. These materials are toxic and to some extent water soluble. Biodegradation will further increase their mobility. Thus, landfill disposal of these wastes represents an excessive, long-term threat to underground water supplies and must be considered much less acceptable than Option No.2 (incineration). Option No.3 is acceptable only when the landfill site is totally isolated from ground and surface water.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Most of the wastes generated by the industries that produce and use these materials can best be handled and treated at the site of generation by incineration. This includes wastes that are presently landfilled by private scavengers. These scavengers could also set up incineration sites in those cases where size and economics make this the preferred method of disposal. Incineration should be available at the National Disposal Site for situations where both the industry generating the waste and the local scavenging industry can not handle the waste safely.

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Ethyl Chloride

IUC Name Chloroethane

Common Names Hydrochloric ether
Muriutic Ether

Structural Formula

C_2H_5Cl

Molecular Wt. 62.54　Melting Pt. -138.7 C(1)　Boiling Pt. 13.1 C(1)

Density (Condensed) .9028 @15/4 C(1)　Density (gas) 2.22 F(2) @

Vapor Pressure (recommended 55 C and 20 C)

2 atm @ 32.5 C(1)　5 atm @ 64.0 C(1)　20 atm @ 127.3 C(1)

Flash Point -58 F (C.C.)　Autoignition Temp. 966 F(2)

Flammability Limits in Air (wt %)　Lower　Upper

Explosive Limits in Air (wt. %)　Lower 3.8%(2)　Upper 15.4%(2)

High fire hazard(2)

Solubility

Cold Water slightly　Hot Water insoluble　Ethanol very

Others: Miscible ether

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in steel cylinders

ICC Classification Flammable liquid - red label　Coast Guard Classification IATA - red label　red label

Comments

References (1) 1570
(2) 0766

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Epichlorohydrin

IUC Name 1-chloro-2,3-epoxypropane

Common Names α-epichlorohydrin
α-chloropropylene oxide
chloromethyloxirane

Structural Formula

C_3H_5ClO

Molecular Wt. 92.53

Melting Pt. -48 C(1) -57.1 C(2) -25.6 C(2)

Boiling Pt. 116.5 C(1)

Density (Condensed) 1.1801 @ 20/4(1)

Density (gas) 3.29 (2) @

Vapor Pressure (recommended 55 C and 20 C)

10 mm @ 16.6 C(2)   100 mm @ 62 C(3)   400 mm @ 98 C(3)

Flash Point 105 F (O.C.)

Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water slightly

Hot Water decomposes

Ethanol -

Others: soluble benzene, ether, chloroform, trichloroethylene, carbon tetrachloride, immiscible petroleum hydrocarbons(3).

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in

ICC Classification

Coast Guard Classification

Comments

References (1) 1570
(2) 0766
(3) 1492

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Dichlorotetrafluoroethane

IUC Name 1,1-dichloro-1,2,2,2-tetrafluoroethane

Common Names F-114 (Freon-114)

Structural Formula

CCl_2FCF_3

$C_2Cl_2F_4$

Molecular Wt. 170.92(2) Melting Pt. -94(2) Boiling Pt. 3.5 C(1)

Density (Condensed) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

13 psig @ 70 F(3) @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble(2) Hot Water insoluble(2) Ethanol soluble(2)

Others: soluble ether(2)

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in steel cylinders

ICC Classification Coast Guard Classification

Comments

References (1) 766 (649)
(2) 1570
(3) Air products catalogue

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name 1,3-dichloropropene

IUC Name 1,3-dichloropropene

Common Names α,γ-dichloropropylene
1,3-dichloropropylene
γ-chloroallyl chloride

Structural Formula

$C_3H_4Cl_2$

Molecular Wt. 110.98 Melting Pt. Boiling Pt. 108 C(1)

Density (Condensed) 1.220(1) @ 25 C(1) Density (gas) 3.8 @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point 93 F(2) Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble Hot Water Ethanol soluble

Others: soluble chloroform

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments The physical constants are for the equilibrium: Mixture of *cis* and *trans* isomers.

References (1) 1492
(2) 0766

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Dichloroethylether

IUC Name 1-chloro-2-(β-chloroethoxy)ethane

Common Names β,β-dichloroethylether, chlorex
sym-dichloroethylether
1,2-dichlorodiethylether

Structural Formula

$C_4H_8Cl_2O$

Molecular Wt. 143.02(1)   Melting Pt. ______   Boiling Pt. ______

Density (Condensed) 1.22 @ 20/20 C(1)   Density (gas) 1.182 @ 19/19 C(2)

Vapor Pressure (recommended 55 C and 20 C)

0.7 mm @ 20 C(3)   100 mm @ 62 C(2)   40 mm @ 91.5 C(2)

Flash Point 131 F (C.C.)(3)   Autoignition Temp. 696 F(3)

Flammability Limits in Air (wt %)   Lower ______   Upper ______

Explosive Limits in Air (wt. %)   Lower ______   Upper ______

Solubility

Cold Water insoluble(1)   Hot Water ______   Ethanol soluble(1)

Others: most organic solvents(1)

Acid, Base Properties ______

Highly Reactive with explosive hazards common with ethers(3); reacts with water, oxidizing materials(3).

Compatible with ______

Shipped in ______

ICC Classification ______   Coast Guard Classification ______

Comments ______

References (1) 1492
(2) 1570
(3) 0766

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Dichlorodifluoromethane

IUC Name Dichlorodifluoromethane

Common Names Freon-12, Frigen-12, Gentron-12,
Isotron-12, Halon, Arcton-6

Structural Formula

CCl_2F_2

Molecular Wt. 120.92(1) Melting Pt. -158 C(1) Boiling Pt. -29 C(1)

Density (Condensed) ____ @ ____ ____ Density (gas) ____ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

5 atm @ 16.1 C(1) 70 psig @ 70 F(1) ____ @ ____

Flash Point ____ Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water insoluble(3) Hot Water ____ Ethanol soluble(2)

Others: soluble ether

Acid, Base Properties neutral

Highly Reactive with non-corrosive(3)

Compatible with ____

Shipped in STEEL CYLINDERS

ICC Classification Non-flammable, green label IATA nonflammable Coast Guard Classification Non-flam., green(1)

Comments ____

References (1) 766
(2) 1570
(3) 1492

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Chloroform

IUC Name Trichloromethane

Common Names

Structural Formula

$CHCl_3$

Molecular Wt. 119.38(1) Melting Pt. -63.5 C(1) Boiling Pt. 61.2 C(1)

Density (Condensed) 1.4916 @ 18 C(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

15 psig @ 84 C(1) 60 psig @ 120 C(1) @

Flash Point non-flammable(2) Autoignition Temp.

Flammability Limits in Air (wt %) Lower non-flammable(2) Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water slightly(2) Hot Water slightly(2) Ethanol miscible(2)

Others: miscible in all proportions ether, acetone, benzene, ligroin(2)

Acid, Base Properties neutral

Highly Reactive with aluminum and magnesium powder; impact sensitive with alkali metals; highly exothermic reaction with alcohols plus base. Forms explosive mixture with nitrogen tetroxide(3).

Compatible with

Shipped in steel drums

ICC Classification Coast Guard Classification

Comments MCA warning label(4); decomposes to phosgene when heated to decomposition(4)
TLV (accepted) 50 ppm; 240 mg/m3(4)

References (1) 1570 (4) 766
(2) 1492
(3) 1569

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. W. Name Chloral hydrate

IUC Name 2,2,2-Trichloro-1,1-ethanediol

Common Names Trichlorocetaldehyde monohydrate

Structural Formula

$C_2H_3Cl_3O_2$

Molecular Wt. 165.42(1) Melting Pt. 57 C(1) Boiling Pt. 98 C(1)

Density (Condensed) 1.9081 @ 20 C(2) Density (gas) ______ @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

10 mm(solid) @ 20 C(2) 100 mm @ 55 C(2) ______ @ ______

Flash Point ______ Autoignition Temp. ______

Flammability Limits in Air (wt %) Lower slight(3) Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility

Cold Water very soluble(1) Hot Water very soluble(1) Ethanol very soluble(1)

Others: very soluble in chloroform, ether, carbon disulfide, glycerol, olive oil, benzene, toluene, turpentine(1)

Acid, Base Properties acidic

Highly Reactive with ______

Compatible with ______

Shipped in ______

ICC Classification ______ Coast Guard Classification ______

Comments Complete medical data in Refs. 2 & 3

References (1) 1492
(2) 1570
(3) 0766

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. W. Name Carbon tetrachloride

IUC Name Tetrachloromethane

Common Names Perchloromethane

Structural Formula

CCl_4

Molecular Wt. 153.82(1) Melting Pt. -22.96 C(1) Boiling Pt. 76.75 C(1)

Density (Condensed) 1.5942 @ 20 C(1) Density (gas) ____ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

100 mm @ 23 C(1) 400 mm @ 58 C(1) ____ @ ____

Flash Point none(2) Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water insoluble(1) Hot Water insoluble(1) Ethanol soluble(1)

Others: miscible in ether, benzene, chloroform, carbon disulfide, petroleum ether, oils.

Acid, Base Properties neutral

Highly Reactive with May be reactive with alkaline or alkaline earth metals under proper conditions(3)

Compatible with ____

Shipped in ____

ICC Classification ____ Coast Guard Classification ____

Comments forms phosphene at high temperatures(2)

References (1) 1570
(2) 0766
(3) 1569

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Ethylene dichloride

IUC Name 1,2-Dichloroethane

Common Names Ethylene chloride
sym.-Dichloroethane, Dutch liquid, Brocide

Structural Formula

$C_2H_4Cl_2$

Molecular Wt. 98.96 Melting Pt. -35 C(1) Boiling Pt. 84 C(1)

Density (Condensed) 1.256 @ 20/4 C(1) Density (gas) 3.35(2) @

Vapor Pressure (recommended 55 C and 20 C)

100 mm @ 29.4 C(2) @ @

Flash Point 56 F(2) Autoignition Temp. 779 F(2)

Flammability Limits in Air (wt %) Lower Upper 60-70%(2)

Explosive Limits in Air (wt. %) Lower 6.2%(2) Upper 15.9%(2)

Solubility

Cold Water SLIGHTLY(1) Hot Water Ethanol very(1)

Others: ∞ ether chloroform(3)

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in

ICC Classification Flammable liquid; red(2) IATA: red(2) Coast Guard Classification red label(2)

Comments

References (1) 1576
(2) 0766
(3) 1492

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. W. Name Perchloroethylene

IUC Name Tetrachloroethene

Common Names Tetrachloroethylene, ethylene tetrachloride, carbon dichloride, many trade names(2)

Structural Formula

C_2Cl_4

Molecular Wt. 165.85 Melting Pt. -23.35 C(1) Boiling Pt. 121.20 C(1)

Density (Condensed) 1.6311 @ 15/4 C(1) Density (gas) ____ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

15.8 mm @ 22 C(1) ____ @ ____ ____ @ ____

Flash Point none Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water 100 ppm(2) Hot Water ____ Ethanol miscible(2)

Others: miscible ether, chloroform, benzene(2)

Acid, Base Properties ____

Highly Reactive with extremely stable and resists hydrolysis(1).

Compatible with ____

Shipped in ____

ICC Classification IATA: other restricted articles, Class A. Coast Guard Classification ____

Comments ____

References (1) 0766
(2) 1492

363

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Propylene dichloride

IUC Name 1,2-Dichloropropane

Common Names

Structural Formula

$C_3H_6Cl_2$

Molecular Wt. 112.99 Melting Pt. -100.42 C(2) Boiling Pt. 96.8 C(1)

Density (Condensed) 1.1593 @ 20/20 C(1) Density (gas) 3.9 @

Vapor Pressure (recommended 55 C and 20 C)

40 mm @ 19.4 C(1) @ @

Flash Point 60 F(1) Autoignition Temp. 1035 C(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 3.4%(1) Upper 14.5%(1)

Solubility

Cold Water slightly(2) Hot Water Ethanol

Others: common organic solvents

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in

ICC Classification Flammable liquid; red label(1) Coast Guard Classification

Comments

References (1) 0766 (646)
(2) 1570 (C-488)

438

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. W. Name Trichloroethylene

IUC Name Trichloroethene

Common Names Ethinyl trichloride, ethylene trichloride, many trade names(2)

Structural Formula

C_2HCl_3

fp -86.8 C(1)

Molecular Wt. 131.39 **Melting Pt.** -73 C (1) **Boiling Pt.** 87.1 C(1)

Density (Condensed) 1.45560 @ 25/4 C(1) **Density (gas)** 4.53(1) @

Vapor Pressure (recommended 55 C and 20 C)

100 mm @ 32 C(1) @ @

Flash Point 90 F(1) **Autoignition Temp.** 770 F(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 2.5%(1) Upper 90%(1)

Solubility

Cold Water slightly Hot Water Ethanol -

Others: soluble in most organic solvents

Acid, Base Properties neutral

Highly Reactive with Should be stored away from light, especially when moist.(2)

Compatible with

Shipped in

ICC Classification IATA: other restricted articles, Class A. **Coast Guard Classification**

Comments

References (1) 0766

(2) 1492

439

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Trichlorofluoromethane

IUC Name Fluorotrichloromethane

Common Names Fluorotrichloromethane, Freon-11

Structural Formula

CCl_3F

Molecular Wt. 137.38 Melting Pt. -111 C(1) Boiling Pt. 24.1 C(1)

Density (Condensed) 1.494 @ 17.2 C(1) Density (gas) ____ @ ____ ° ____

Vapor Pressure (recommended 55 C and 20 C)

____ @ ____ ° ____ @ ____ ° ____ @ ____ °

Flash Point ____ ° Autoignition Temp. ____ °

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water ____ Hot Water ____ Ethanol ____

Others: ____

Acid, Base Properties neutral

Highly Reactive with ____

Compatible with ____

Shipped in ____

ICC Classification ____ Coast Guard Classification ____

Comments ____

References (1) 0766

HAZARDOUS WASTES PROPERTIES WORKSHEET

497

H. M. Name Hexachlorophene

IUC Name (2-hydroxy-3,4,6-trichlorophenyl) methane

Common Names Hexosan
G-11
2,2'-Methylene bis (3,4,6-tricholophenol)

Structural Formula

$C_{13}H_6Cl_6O_2$

Molecular Wt. 406.9 Melting Pt. 165 C(1) Boiling Pt. ______

Density (Condensed) ______ @ ____ ____ Density (gas) ______ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

______ @ ______ ______ @ ______ ______ @ ______

Flash Point ______ Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ______ Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility

Cold Water soluble (ph >9-10)(2) Hot Water ______ Ethanol soluble(2)

Others: soluble ether, acetone, chloroform

Acid, Base Properties weakly acidic

Highly Reactive with ______

Compatible with ______

Shipped in ______

ICC Classification ______ Coast Guard Classification ______

Comments ______

References (1) 0766
(2) 1570

140

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name o-Dichlorobenzene

IUC Name 1,2-Dichlorobenzene

Common Names

Structural Formula

$C_6H_4Cl_2$

Molecular Wt. 147.01 Melting Pt. -17 C(1) Boiling Pt. 179 C(1)

Density (Condensed) 1.3048 @ 20/40 C(1) Density (gas) 5.05(2) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point 151 F(2) Autoignition Temp. 1198 F(2)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 2.2% Upper 9.2%

Solubility

Cold Water insoluble(1) Hot Water Ethanol soluble(2)

Others: soluble ether, benzene(3)

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in

IATA: other restricted articles, class A; no label, no limit.

ICC Classification Coast Guard Classification

Comments Similar in toxic effects to chlorobenzene, ortho isomer is probably more toxic than meta and para isomers.(2)

References (1) 1570
(2) 0766
(3) 1492

141

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name p-Dichlorobenzene

IUC Name 1,4-Dichlorobenzene

Common Names

Structural Formula

$C_6H_4Cl_2$

Molecular Wt. 140.01 Melting Pt. 53 C(1) Boiling Pt. 174 C(1)

Density (Condensed) 1.533 @ 0/4 C(1) Density (gas) 5.08(2) @

Vapor Pressure (recommended 55 C and 20 C)

10 mm @ 54.8 C(2) @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble(1) Hot Water Ethanol slightly(1) soluble, hot(1)

Others:

Acid, Base Properties neutral

Highly Reactive with

Compatible with

Shipped in

IATA: other restricted cargos, class A; no limit.

ICC Classification Coast Guard Classification

Comments

References (1) 1570
(2) 0766
(3) 1492

HAZARDOUS WASTES PROPERTIES WORKSHEET

436

H. M. Name Trichlorobenzene

IUC Name 1,2,4-Trichlorobenzene

Common Names unsym.-Trichlorobenzene

Structural Formula

$C_6H_3Cl_3$

Molecular Wt. 181.46　Melting Pt. 16.9 C(1)　Boiling Pt. 213-213 C(1)

Density (Condensed) 1.4542 @ 20/4 C(1)　Density (gas) 6.26(3) @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

10 mm @ 78.0 C(3)　______ @ ______　______ @ ______

Flash Point 225 F (C.C.)(3)　Autoignition Temp. ______

Flammability Limits in Air (wt %)　Lower ______　Upper ______

Explosive Limits in Air (wt. %)　Lower ______　Upper ______

Solubility

Cold Water insoluble(1)　Hot Water ______　Ethanol slightly(1)

Others: miscible - ether, benzene, carbon disulfide, petroleum ether(2)

Acid, Base Properties ______

Highly Reactive with ______

Compatible with ______

Shipped in ______

ICC Classification ______　Coast Guard Classification ______

Comments steam volatile(2)

References (1) 1570 (C-171)
(2) 1492 (1059)

108

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Chlorobenzene

IUC Name Chlorobenzene

Common Names Phenyl chloride
Chlorobenzol
Monochlorobenzene

Structural Formula

C_6H_5Cl

Molecular Wt. 112.56(1)   Melting Pt. -45 C(1)   Boiling Pt. 131-2(2)

Density (Condensed) 1.107 @ 20 C(2)   Density (gas) 3.88(3) @

Vapor Pressure (recommended 55 C and 20 C)

10 mm @ 22 C   40 mm @ 50 C(1)   @

Flash Point 28 C(2)   Autoignition Temp. >1245 F(3)

Flammability Limits in Air (wt %)   Lower Dangerous when exposed to flame(3)   Upper

Explosive Limits in Air (wt. %)   Lower 1.8 (212 F)   Upper 9.6 (302 F)(3)

Solubility

Cold Water insoluble(2)   Hot Water   Ethanol very soluble(2)

Others: very soluble benzene, chloroform, ether(2)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Flammable liquid(3)   Coast Guard Classification Flammable liquid(3)

Comments

References (1) 1570
(2) 1492
(3) 0766

PROFILE REPORT ON LEAD COMPOUNDS

Lead Acetate (234), Lead Carbonate (237) Lead Chlorite (238), Lead Nitrate (240), Lead Nitrite (241)

1. GENERAL

Introduction

In spite of its position in Group IVb of the periodic table, the usual valence of lead in its compounds is +2 instead of +4. In many properties the bivalent lead compounds resemble those of some of the alkaline earth elements such as barium and strontium. They also show a remarkable tendency toward forming basic salts of both anhydrous and hydrated types. Lead forms a soluble acetate, nitrate, nitrite, a slightly soluble chlorite, and an insoluble carbonate.

Among the five lead salts covered in this report, the chlorite and nitrite are not known to have any significant commercial and industrial consumption as reflected by the fact that no producer or distributor of these two compounds in the United States is listed in the major references of chemical suppliers.[1571,1670,1790] Consequently, the emphasis of this Profile Report will be placed on the acetate, carbonate, and nitrate. However, any pertinent information for the chlorite and nitrite will be included whenever they are available.

Lead Acetate

Lead acetate, $Pb(C_2H_3O_2)_2 \cdot 3H_2O$, is also known as plumbous acetate or sugar of lead. It is a colorless monoclinic crystal or white granules or powder. It is poisonous.[1492] It is manufactured by dissolving litharge (PbO) in hot dilute aqueous acetic acid solution.[2272] On cooling, large crystals are formed and can be separated by filtration. Its uses are:

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1) manufacture of other lead salts as basic lead carbonate and lead chromate;
2) as a mordant in dyes;
3) as a drier in paints;
4) lead-coating of metals;
5) as an analytical reagent;
6) as an astringent on unbroken skin and mucous membranes;
7) as an astringent and sedative on bruises and superficial inflammatory conditions for animals;
8) formerly used internally as an astringent for diarrhea and in form of rectal suppositories for hemorroids.

Lead Carbonate

Normal lead carbonate, $PbCO_3$, occurs naturally as the mineral cerussite. It is a white to grayish ore found in conjunction with other lead minerals, being formed by the action of carbonated water on galena (lead sulfide) or its oxidation products. In the pure state, it is a colorless crystal or rhombic form. It is practically insoluble in water. It has a limited use in the paint and ceramic industries. More important commercially, and manufacturered in larger tonnage, however, is the basic lead carbonate, $2PbCO_3 \cdot Pb(OH)_2$, also known as the white lead.[1433] It is a heavy, white powder, insoluble in water and alcohol.

White lead is formed when various basic salts of lead are treated with CO_2. Commercially, metallic lead or litharge, PbO, is used.[2273] CO_2 gas is passed through an aqueous solution of litharge in the presence of a small quantity of acetic acid. A series of chemical reactions is believed to take place as follows.[2275] First, litharge is hydrolzed to form lead hydroxide which reacts with acetic acid to form normal (or neutral) lead acetate. The latter dissolves additional lead hydroxide to yield basic lead acetate. Finally, CO_2 reacts with basic lead acetate to yield basic lead carbonate and reproduce normal lead acetate. The basic lead carbonate formed is precipitated and separated from the solution by filtration. The filtrate is recycled to digest more litharge. So, the acetic acid plays the role of catalytic agent in the cycle with normal lead acetate acting as a solvent for lead hydroxide.

Currently, white lead is one of major pigments in making white paint. However, due to its poisoning effect, particularly to small children, its use in house paint is an environmental issue and its future is somewhat uncertain. Basic lead carbonate is also used in cements, in making putty and lead carbonate paper, and in the processing of parchment.[1492]

Lead Nitrate

Lead nitrate, $Pb(NO_3)_2$, forms colorless cubic or monoclinic columnar crystals. It is highly soluble in water and poisonous.[1492] It is manufactured by reacting litharge (PbO) or metallic lead, or lead carbonate with nitric acid.[2274] Its uses are:[1492]

1) manufacture of matches and special explosives;
2) as a mordant in dyeing and printing on textiles;
3) manufacture of other lead salts;
4) as a mordant for staining mother-of-pearl, horn;
5) as an oxidizer in dyes industry;
6) as sensitizer in photography;
7) process engraving;
8) as a chemical reagent;
9) formerly, as an astringent and antiseptic for external use.

Other Lead Compounds

Very little information is available regarding the properties, manufacturing methods, and uses for lead chlorite and nitrite. Pertinent data available are presented as follows:[0766,1433,1492]

Lead chlorite, $Pb(ClO_2)_2$, is a yellow crystal of monoclinic form. It is slightly soluble in water. Upon heating to 126 C, it explodes. Hence, it causes a severe explosion hazard when exposed to heat. Lead nitrite, $3PbO \cdot N_2O_3 \cdot H_2O$, is a light yellow powder or crystal. It is a powerful oxidizing agent, thus a potential fire and explosion hazard, however, the details of such hazards are unknown. It is also listed as poisonous.[1492] Large amounts taken by mouth may produce nausea, vomiting, cyanosis, collapse and coma.

Sources and Types of Wastes

The wastes from the lead compounds under consideration in this report may come from the following sources:

1) lead compound manufacturers;
2) lead compound distributors;
3) paint and dye formulators and users;
4) manufacturers of matches and pyrotechnics;
5) laboratories and plants using lead salts as chemical reagents;
6) manufacturers of lead carbonate paper;
7) medical and veterinary facilities.

Generally, lead compound wastes can be grouped into diluted or concentrated wastes. In the manufacture of the lead salts, the products are separated from the aqueous reaction solution by precipitation and filtration. The filtrate is recycled, but eventually becomes a diluted waste of lead compounds. The concentrated lead waste may include any unused or contaminated lead compounds or any other lead-containing substances such as white paints or dyes.

Physical and Chemical Properties

The physical and chemical properties of five lead salts are given in the attached worksheets.

2. TOXICOLOGY

All of the lead compounds are sufficiently soluble in digestive juices to be considered toxic.[1433] In general, lead poisoning may be caused by 1) inhalation of dusts, fumes or vapors; 2) ingestion of lead compounds;

and 3) absorption through the skin. However, there is no evidence that inorganic lead compounds can be absorbed through the skin in sufficient quantities to produce lead intoxication.[1433]

Lead is a cumulative poison.[0766] Increasing amounts of lead could build up in the body and eventually a point is reached where symptoms and disability occur. The symptoms of lead poisoning may be classified according to their clinical picture as: 1) aliminetary; 2) neuromotor; and 3) encephalic.

The alimentary type occurs most frequently. It is characterized by abdominal discomfort or pain. Other complaints are constipation and/or diarrhea, loss appetite, metallic taste, nausea and vomiting, lassitude, insomnia, joint and muscular pains, irritability, headache and dizziness. In the neuromuscular type, the chief complaint is weakness, frequently of the extensor muscles of the wrist and hand, unilateral or bilateral. Gastroenteric symptoms are usually present, but not as severe as in the alimentary type of poisoning. Lead encephalopathy is the most severe but the rarest manifestation of lead poisoning. It may be caused by rapid and heavy lead absorption. Lead encephalopathy begins abruptly, and is characterized by signs of cerebral and meningeal involvement. There is usually stupor, progressing to coma, with or without convulsion, and often terminating in death.

For treatment of lead poisoning, it has been found that the chelating agent, calcium ethylenediaminetetracetate (CaEDTA), and related compounds are highly efficacious in removing absorbed lead from the tissues of the body. CaEDTA is effective only when administered intravenously.

Of the various lead compounds, the carbonate, monoxide, and sulfates are considered to be more toxic than metallic lead or other lead compounds. The Threshold Limit Value (TLV) for lead in air recommended by the American Conference of Governmental Industrial Hygienists, 1971, is 0.15

mg/M^3. The lethal doses reported for the lead compounds are given below:[1312]

1) Lead acetate:

iv LD_{50}	120 mg/kg, rat
ip LD_{50}	150 mg/kg, rat

2) Lead carbonate (neutral):

ip LD_{CA}	124 mg/kg, guinea pig

Lead carbonate (basic):

MLD, orally	1.0 g/kg, guinea pig

3) Lead nitrate

ip LD_{CA}	270 mg/kg, rat

4) Lead chlorite and Nitrite: No data

The U.S. Public Health Service has established the limits and ranges of lead concentrations in public water affecting human health as follows:[1752]

(A) Physiologically safe:

Lifetime	0.05 mg/l
Short period, a few weeks	2-4 mg/l

(B) Harmful range:

Borderline	2-4 mg/l for 3 months
Toxic	8-10mg/l for several weeks
Lethal	Unknown, but probably more than 15 mg/l for several weeks

Lead in soft water is highly toxic to certain fish; 0.1 mg/l is toxic to small sticklebacks, larger fish are somewhat less susceptible to lead poisoning.

For lead nitrate, there is an additional toxic effect. Serious and occasionally fatal poisonings in infants have occurred following ingestion of well waters shown to contain nitrate (NO_3^-). This has occurred with sufficient frequency and widespread geographic area to require an assigned limit to the concentration of nitrate in drinking water. The limit recommended by the U.S. Public Health Service is 10 mg nitrate nitrogen (or 45 mg nitrate) per liter of water.[1752]

3. OTHER HAZARDS

Lead nitrate is a powerful oxidizing agent. Fire hazard is moderate. It may also explode when shocked, exposed to heat or flame or by spontaneous chemical reaction.

Lead nitrite is also a powerful oxidizing agent. However, little is known about its details on fire and explosion hazards.

Lead chlorite causes a severe explosion hazard when exposed to heat.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, and Transportation

Because of the hazard of lead poisoning, special care must be exercised in the handling, storage and transportation of all lead compounds. In storage, they should be kept in the original containers supplied by the manufacturers and away from feed and food products. Powerful oxidizing agents, such as lead nitrate and lead nitrite, should be kept away from materials which are either flammable or susceptible to oxidation easily. To prevent explosion caused by spontaneous chemical reaction, the nitrate, nitrite, and chlorite should be stored in cool and well-ventilated areas.

In handling the lead compounds, the most important thing is to avoid breathing any lead-containing dusts, fumes, or vapors. Therefore, the use of respiratory protective devices is recommended. In shipping, lead acetate is labeled as Class B poison and lead nitrate, as oxidizing material. They must be shipped in accordance to DOT or IATA regulations.

Disposal Reuse

Contaminated lead compound wastes could be reprocessed. The main consideration is the economic feasibility. The safe disposal of these compounds is here defined in terms of the recommended Threshold Limit Value (TLV) maximum concentrations released to the atmosphere and to the water source for marine habitat and/or potable water.

These maximum allowable concentrations are given below:

Contaminant in Air	Explosure Limit	Basis for Recommendation
Lead Acetate	0.0015 mg as Pb/M^3/24 hrs.	.01 TLV
Lead Carbonate	"	"
Lead Chlorite	"	"
Lead Nitrate	"	"

Contaminant in Water	Explosure Limit	Basis for Recommendation
Lead Acetate	0.05 mg as Pb/l	U.S. Public Health Service, Drinking Water Standards
Lead Carbonate	"	"
Lead Chlorite	"	"
Lead Nitrate	"	"

5. EVALUATION OF WASTE DISPOSAL PROCESSES

Dilute Waste

Option No. 1 - Filtration and Settling of Lead Carbonate. This option is specifically for the removal of lead carbonate from its reaction solution. Since lead carbonate is scarcely soluble in water, it can be economically removed from water by simple filtration. For example, at 20 C, only 0.11 mg of normal lead carbonate dissolves in one liter of water. This is equivalent to 0.085 mg Pb/l and is not far above the recommended maximum allowable concentration of 0.05 mg Pb/l in water. Furthermore, in filtration practice, the filter cake is washed with fresh water.

So the actual concentration of lead in resulting filtrate is below its saturation solubility value. To reduce the lead content of the contaminated filtrate stream to a value below the maximum allowable concentration, proper amount of ammonium carbonate can be added. In current industrial practice, the contaminated filtrate stream is discharged to a settling pond. 2273 Periodically, the deposit from the pond is removed and sent to a smelter to recover its lead content. The waste liquid can be safely discharged.

Option No. 2 - Sulfide Precipitation. Three of the lead compounds in this report, the acetate, nitrate, and nitrite are very soluble. Even for the less soluble lead chlorite, removal of lead from an aqueous waste stream by simple filtration is no longer satisfactory. The filtrate still contains too high a lead concentration. Therefore, it is necessary to convert them into an insoluble compound. The general practice is to convert the soluble lead salts into the insoluble lead sulfide using hydrogen sulfide.[2272] The lead sulfide precipitate is removed by filtration. The filtrate is treated as described in Option No. 1.

Option No. 3 - Carbonate Precipitation. Similar to Option No. 2, soluble lead salts can also be removed from water as insoluble lead carbonate, using ammonium carbonate. The handling and treatment of the contaminated waste stream is similar to that of Option No. 2.

Concentrated Waste

Option No. 1 - Conversion to Sulfide. Contaminated solid wastes of lead compounds are generally treated with concentrated nitric acid to form the nitrate which is then converted to lead sulfide by hydrogen sulfide.[0095] The insoluble lead sulfide is removed by filtration and sent to a smelter to recover its lead content. The filtrate may be treated as described previously.

Option No. 2 - Landfill. Disposal of soluble lead compounds such as the acetate, nitrate and nitrite by landfill technique is totally unacceptable. Even the slightly soluble lead chlorite should not be disposed of by landfill. However, lead carbonate is practically insoluble in water and, in fact, occurs naturally as the mineral cerussite. Similiarily, lead sulfide is also insoluble in water and occurs naturally as the mineral galena. Therefore, disposal of these two lead compounds by the landfill technique might be considered if they are not contaminated with any soluble lead compounds.

In summary, the best method for disposal lead waste is to precipitate the lead out either as carbonate or as sulfide. The technique is efficient and adequate for industrial practices.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Since lead is toxic in nature and not very cheap as a raw material, it is a common practice for the lead compound manufacturers to recycle the waste streams and to recover the waste product. Furthermore, the precipitation methods for the removal of lead from spent aqueous reaction solutions is effective and inexpensive enough for all lead compound manufacturers or users to operate. It is concluded that the disposal of fairly concentrated lead waste is currently handled adequately at the industrial site level and does not warrant consideration for the treatment at the National Disposal Site. Mixed wastes containing significant quantities of soluble lead compounds, however, must be be isolated from ground and surface waters.

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

#234

H. M. Name Lead Acetate

IUC Name

Common Names

Structural Formula

$Pb(C_2H_3C\ )_2 \cdot 3H_2O$

Molecular Wt. 379.34(1) Melting Pt. 75 C (1) Boiling Pt. decomposes @ 200 C

Density (Condensed) 2.55 @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 45.61 g/100 cc @ 15 C Hot Water 200 g/100 cc @ 100°C Ethanol insoluble

Others: soluble in glycerol

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570
(2)

#237

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead Carbonate, basic

IUC Name

Common Names

Structural Formula

$2PbCO_3 \cdot Pb(OH)_2$

Molecular Wt. 775.67 Melting Pt. decomposes @ 400 C Boiling Pt.

Density (Condensed) 6.14 @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble Hot Water insoluble Ethanol insoluble

Others: soluble in HNO_3

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

#238

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead Chlorite

IUC Name

Common Names

Structural Formula

$Pb(ClO_2)_2$

Molecular Wt. 342.09
Melting Pt. explodes @ 126 C
Boiling Pt.

Density (Condensed) @
Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@
@
@

Flash Point
Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper
Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.095 g/100 cc @ 20 C
Hot Water 0.42 g/100 cc @ 100 C
Ethanol

Others: soluble in KOH

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification
Coast Guard Classification

Comments

References (1) 1570

#240

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead Nitrate

IUC Name

Common Names

Structural Formula

$Pb(NO_3)_2$

Molecular Wt. 331.20 Melting Pt. decomposes @ 470 C Boiling Pt.

Density (Condensed) 4.53 @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 37.65 g/100 cc @ 0 C Hot Water 127 g/100 @ 100 C Ethanol 8.77 @ 22 C in 43% alcohol

Others: soluble in alkali, NH_3

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

#241

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead Nitrite

IUC Name

Common Names

Structural Formula

$3PbO \cdot N_2O_3 \cdot H_2O$

Molecular Wt. 763.60 Melting Pt. Boiling Pt.

Density (Condensed) @ Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water very soluble Hot Water Ethanol

Others: soluble in dil HNO_3

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

PROFILE REPORT
Manganese Sulfate (252) and Manganese Chloride (501)

1. GENERAL

Production

There are several producers of $MnSO_4$ in the United States, including the Diamond Shamrock Chemical Company, Baltimore, Maryland,[2178, 2191, 2263] Eastman Chemical Products, Inc., Kingsport, Tennessee, and the Carus Chemical Company, Inc., La Salle, Illinois.[2279] Diamond Shamrock makes $MnSO_4$ by leaching oxide ores with sulfuric acid and concentrating the filtrate. The acid insoluble residues, which consist mostly of silicon dioxide, are dried by evaporation and carted away to serve as landfill.[2178] Eastman Chemical Products and the Carus Chemical Company produce $MnSO_4$ as a byproduct of their production of hydroquinone.[2279] Aniline is oxidized by MnO_2 in the presence of H_2SO_4 to quinone. The quinone is then vacuum-distilled and reduced by iron metal filings to hydroquinone. The solid residue contains $MnSO_4$, which is isolated, crystallized, and packaged and shipped.

Diamond Shamrock is the only producer of manganese chloride. The process is the same as that used for the sulfate with hydrochloric acid replacing sulfuric acid as the leaching agent. Production of $MnCl_2$ amounts to under 2,000 tons/yr, which currently sells for 21 cents/lb. In 1964, 34,169 tons of $MnSO_4$ were produced. Current prices range from $82 to $100/ton, depending on the manganese content.

Use

Manganese sulfate is used almost exclusively for agricultural purposes.[2178, 1433] It is applied as a spray containing 4 lb $MnSO_4$/50 gal water to citrus fruits and truck crops grown in Mn-deficient soils, e.g., Florida and Rhode Island. It is an essential element in plant and animal growth. In plants it appears to catalyze the production of chlorophyll, even though it is not an integral part of the molecule, as is magnesium. Manganese sulfate is also beneficial in the neutralization of alkaline soils. Applications vary from 30 lb/acre for Rhode Island truck crops to 100 lb/acre for Florida citrus fruits.[1433] The addition of manganese sulfate to livestock feed prevents skeletal and reproductive abnormalities and disorders of the central nervous system.[0277] Typical additions are 60 mg/lb feed for poultry.[1492]

A small, undisclosed amount of manganese sulfate is used in the manufacture of pharmaceuticals.

Small quantities of manganese chloride are used in the electrolytic refining of magnesium metal.[2178, 1433] The manganese alloys with the magnesium and induces the precipitation of iron impurities. Kirk-Othmer[1433] reports that another use for manganese chloride is in the manufacture of bricks; the manganese chloride is volatilized in the kiln to impart a dark-red finish to face brick. However, communications with the Los Angeles County Air Pollution Control District [2268] and three Southern California brick manufacturers[2265, 2266, 2267] indicates that $MnCl_2$ is not used in the industry. One manufacturer does,on occasion,add manganese oxide to his charge to impart the red color. It is unlikely that brick manufacturing in other parts of the United States is conducted substantially differently, so it may be concluded that the use of $MnCl_2$ in this industry has essentially evaporated.

2. TOXICOLOGY

Health and Safety Standards and Epidemiology

Manganese and manganese compounds have Threshold Limit Values (TLV) of 5 mg/m^3. The chloride and the sulfate, however, have proved far less toxic than manganese metal. While 11 mg/m^3 of manganese metal have produced toxic effects in man, laboratory experiments with mice have shown that the approximate LD 50 for $MnCl_2$ is 210 mg/kg administered subcutaneously and the LD 50 for $MnSO_4$ is 44 mg/kg administered intraperitoneally.

The manganese used in magnesium metallurgy is completely contained in the magnesium product; there is no mangenese waste. Reports in the literature[1433] that $MnCl_2$ is commonly volatilized in brick kilns were not able to be substantiated. Responses from government agencies and brick manufacturers were consistently negative.[2215,2266,2267,2268]

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Laboratory studies have shown that manganese chloride and manganese sulfate are relatively non-toxic. No incidences of poisoning in man attributable to these substances were found. These materials are quite stable and well-characterized, so it is unlikely that a future problem will arise. It may therefore be concluded that their handling, storage, and transportation are adequate.

Option No. 1 - Use of Acid-Insoluble Residues as Landfill

The use for landfill of the insoluble residues from the production of manganese sulfate and manganese chloride by acid leaching is satisfactory. These residues consist mostly of silicon dioxide, with some highly-insoluble manganese oxides included. There is no air emission or leaching into any ground water.

Option No. 2 - Permanent Storage in a Lagoon of Solid Waste from Hydroquinone Production

The permanent storage of manganese as the insoluble $Mn(OH)_2$ in lagoons is satisfactory. The overflow of less than one ppm is acceptable; it compares very favorably with the U. S. Public Health Service drinking water standard of one ppm Mn.[2118] There are no air emissions.

Option No. 3 - Use of Manganese Sulfate in Fertilizer

Manganese sulfate is heavily used as a fertilizer component in the Florida citrus industry. The Florida State Air and Water Pollution Control Board[2278] actively monitors air and water emissions for manganese. All measurements are found to be well within the set limits, so it may be concluded that the use of manganese sulfate in agriculture does not present a hazard.

The epidemiology of manganese and manganese compounds is discussed more fully in the profile report on manganese (499).

3. OTHER HAZARDS

Manganese chloride and manganese sulfate are quite stable. Manganese chloride vapor reacts slowly with moist air to form HCl and MnO.[1433]

4. DEFINITION OF WASTE MANAGEMENT PRACTICES

Handling, Storage, and Transportation

The U.S. Interstate Commerce Commission has no special requirements or restrictions for the transportation of manganese chloride or manganese sulfate. The materials are probably handled and stored with no special precautions.

Disposal/Reuse

Since manganese sulfate is used as an additive to naturally-deficient soils and livestock feed, its disposition in soil run-off and meat is no greater than that resulting from soils possessing an amount sufficient to sustain healthy life.

The acid insoluble residue from the Diamond Shamrock production of $MnSO_4$ by leaching with sulfuric acid is dried by evaporation and carted away to serve as landfill.[2178] All Mn - containing waste from the production of $MnSO_4$ as a byproduct of hydroquinone is moved to a lagoon, where the manganese is precipitated with lime as $Mn(OH)_2$. The overflow from the lagoon contains less than one ppm Mn, which is below the limit set by the State of Illinois.[2279] There is no air emission except for an occassional, accidental release of quinone.

There is no waste manganese chloride from its use in the electrolytic refining of magnesium.

6. CONCLUSIONS, RECOMMENDATIONS, AND APPLICABILITY TO NATIONAL DISPOSAL SITES

Since manganese chloride and manganese sulfate are relatively nontoxic and are being handled and treated adequately at the industrial level, they are not candidates for National Disposal Sites.

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name 252

IUC Name Manganous Sulfate

Common Names Manganese Sulfate

Structural Formula

$MnSO_4$

Molecular Wt. 151 (1) Melting Pt. 700 C (1) Boiling Pt. decomposes 850 C

Density (Condensed) 3.25 g/cc @ 20 C Density (gas) ____ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

____ @ ____ ____ @ ____ ____ @ ____

Flash Point ____ Autoignition Temp. ____

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water 52 g/100 ml Hot Water 70 g/100 ml Ethanol soluble

Others: insoluble in ether

Acid, Base Properties acidic

Highly Reactive with ____

Compatible with ____

Shipped in tank cars

ICC Classification None Coast Guard Classification None

Comments no restrictions on shipment

References (1) 1433

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name 501

IUC Name Manganese Dichloride

Common Names Manganese Chloride

Structural Formula

$MnCl_2$

Molecular Wt. 125.8 (1)   Melting Pt. 650 C (1)   Boiling Pt. 1190 C

Density (Condensed) 2.977 @ 25 C   Density (gas) ____ @ ____ ____

Vapor Pressure (recommended 55 C and 20 C)

____ @ ____   ____ @ ____   ____ @ ____

Flash Point ____   Autoignition Temp. ____

Flammability Limits in Air (wt %)   Lower ____   Upper ____

Explosive Limits in Air (wt. %)   Lower ____   Upper ____

Solubility

Cold Water 62.2 g/100 ml   Hot Water 123.8 g/100 ml   Ethanol soluble

Others: insoluble in ether, NH_3

Acid, Base Properties acidic

Highly Reactive with ____

Compatible with ____

Shipped in tank cars

ICC Classification None   Coast Guard Classification None

Comments no restrictions on shipment

References (1) 1433

PROFILE REPORT

Organic Mercury (258)

1. GENERAL

Introduction

The organic compounds of mercury comprise a diverse group of materials distinguished by the presence of atoms of mercury joined to organic molecular structures through chemical bonds. By contrast to the long history of use of metallic mercury and its inorganic compounds, organic mercury compounds have been important articles of commerce for a relatively brief period of time. The development of many of the most important members of this group of materials was motivated by the need to find replacements for inorganic mercurials, particularly for agricultural use, that would provide greater efficiency and lower toxicity to plants, animals and man.[1618]

Although the promise of improved efficiency has been, to a great extent, fulfilled by the organic mercury compounds, their affect on the environment has been less salutary. Indeed the tragic incident at Minamata, Japan, the high levels of mercury found in tuna and swordfish and the discovery of the facile, biological conversion of mercury and its compounds to methyl mercury have brought into question the wisdom of any large scale use of mercury and its inorganic and organic compounds.[1951] Recognition of the extent of the problem of mercury pollution has prompted a determined effort to define more efficient methods of disposal and control, and a search for safer substitutes for all current applications of mercury and mercurials.

Preliminary figures[2190] for organic mercury consumption in the United States in 1971 are: agricultural (includes fungicide and bactericides for industrial purposes), 1,477 flasks (one flask equals 76 lb); antifouling paint, 414 flasks; mildew proofing paint, 8,191 flasks; and pharmaceuticals, 682 flasks. Total consumption of all mercury and mercury compounds for 1971 is estimated at more than 52,000 flasks.[2190]

Manufacture

Mercury compounds of the aliphatic series[1618] Aliphatic mercury compounds of the general formula (I) are produced by the reaction of a dialkylmercury with the appropriate mercury salts:

$$R_2Hg + Hg(Ac)_2 \rightarrow \underset{(I)}{2RHgAc}$$

The dialkylmercury necessary for this synthesis is prepared industrially by two methods:

(1) Reaction of alkyl halides with amalgams of the alkali metals (most often sodium amalgam):

$$2RBr + Hg + 2Na \rightarrow R_2Hg + 2NaBr$$

The process is carried out in the presence of catalysts and at low temperatures.

(2) Reaction of the appropriate organomagnesium compounds with mercuric chloride:

$$R + Mg \rightarrow RMg + 2RMgX + HgCl_2 \rightarrow R_2Hg + MgX_2 + MgCl_2$$

A new method for preparing alkylmercury salts by initiated breakdown of the mercury salts of the carboxylic acids has been suggested by G. A. Razuvaev:

$$(HgOCOCH_3)_2 \rightarrow CH_3HgOCOCH_2 + CO_2$$

Hydrogen peroxide or inorganic peroxide are used as initiators.

It has also been proposed that ethylmercury salts be prepared from tetraethyllead and mercuric chloride:

$$(C_2H_5)_4Pb + 2HgCl_2 \rightarrow (C_2H_5)_2PbCl_2 + 2C_2H_5HgCl$$

Mercury compounds of the aromatic series[1618] A number of methods are known for the synthesis of mercury compounds of the aromatic series that are suitable for industrial production.

One of the principal methods of producing phenylmercury derivatives is the direct mercuration of benzene which takes place in >90 percent yield when mercuric acetate or other mercury salts of carboxylic acids are heated with benzene.

A second method of synthesizing phenylmercury derivatives is the Nesmeanov reaction, in which the yield of phemymercuric halides amounts to 70 to 85 percent.

Total production of cyclic mercury fungicides for the year 1970 was $1,571 \times 10^3$ lb, of that amount, 457×10^3 lb, or 29 percent, was phenylmercuric acetate.[1718]

Uses[0533]

Agriculture. The primary use of mercury in agriculture has been for seed treatment of cereal grains (phenyl mercuric acetate, methoxyethylmercury). Secondary uses are for disease control of fruits, vegetables, etc. Mercurial disease control usage has a long history of successful application with the added advantage of being relatively inexpensive. The major commercial applications are with generally mature products vulnerable to being supplanted by newer and/or more effective materials. Therefore, the opportunities for increased usage and new applications are either nonexistent or severely limited.

The search for suitable, non-mercurial, substitutes has intensified in recent years. However, there is general agreement in the industry that there is not currently available a product affording the broad spectrum control provided by mercury compounds.

Catalysts. Organic mercurial salts (mercuric acetate, phenylmercuric oleate) are used in urethane elastomers for casting, sheeting and sealant applications, frequently as a replacement for stannous octoate catalysts. The availability of suitable substitutes for organic mercury-based catalysts varies with the particular process under consideration.

Paints. Organomercurial compounds (e.g., phenyl mercuric acetate) are the most widely used bactericide/fungicide products in the paint industry, accounting for about 80 percent of dollar sales of such protective paints. Efficiency/cost comparisons with other preservatives invariably demonstrate the superiority of mercurials in providing both shelf preservation and exterior protection. However, higher cost non-mercurial substitutes now exist for use in paints and they will probably see increased use in the future. Most of the currently available substitutes are also organic metallic (Zn, Pb) and their long-term effect on the environment is not yet known.

Paper and Pulp. Substantial use of mercury compounds as slimicides in the pulp and paper industry has continued to decline though they have a high degree of effectiveness where other types of products have failed. The decline in use is due to government prohibition of the use of food packaging paper that have come in contact with mercury compounds and tighter pollution controls on pulp mill effluent water. The organic mercury slimicides (principally, aliphatic mercurials) are being replaced by organotin compounds.[1618]

Pharmaceuticals. Mercury is used in a variety of well defined pharmaceutical and cosmetic applications. These include diuretics (mercurin), antiseptics (merthiolate), and preservatives (phenylmercuric acetate). Substitutes exist for many of the pharmaceutical uses of organic mercury compounds.

Sources and Types of Organic Mercury Wastes

Organic mercury wastes may arise from the manufacture of pesticides, pharmaceuticals, slimicides, explosives and paints, as well as their use in hospitals, pulp and paper manufacture, farming, home and ship building, and photographic processing.

Organic mercury wastes can be classified as diluted or concentrated. Dilute organic mercury wastes include those generated in the waste streams of manufacturers, and formulators, as well as contaminated formulations such as pesticides and paints containing small percentages of organic mercury compounds. Concentrated wastes include any unused or contaminated organic mercury compound unfit for its intended use.

Chemical and Physical Properties

The number and diversity of the organic mercury compounds now in use precludes the preparation of property worksheets for all of them. However, worksheets have been attached covering the chemical and physical properties of phenyl mercuric acetate because of its position as the organic mercury compound with by far the largest sales volume, and of methyl mercury, believed to be the most widespread and potentially the most dangerous form of organomercury in the environment.

2. TOXICOLOGY

Organic mercury compounds may enter the body by inhalation, skin absorption or ingestion.[2036] There is evidence that inhalation of organic mercury vapor and aerosols may be more detrimental than the other means of entry since absorption through the respiratory tract leads to a higher rate of accumulation of mercury in the brain.[0533]

The toxicologic effects of organomercurials are strongly influenced by the nature of the organic portion of the molecule. Short chain alkyl mercury compounds (e.g., methyl and ethyl mercury) are relatively stable in the body and may circulate for a long time unchanged in the blood; methyl mercury has a biological half-life in man of about 70 days.[2036] The stability of the alkyl mercurials, particularly methyl mercury, favors their accumulation in the body where they are found principally in the brain. Thus, more than 98 percent of the mercury found in the brain is in the form of methyl mercury.[2036]

Aromatic mercury compounds (e.g., phenyl mercury, phenyl mercuric acetate), methoxyalkyl mercurials (e.g., methoxyethyl mercury) and most other organic mercury compounds are degraded to inorganic mercury in the body. Therefore, the physiological and toxicological behavior of the non-alkyl organomercurials resembles that of inorganic mercury compounds, with preferential accumulation in the kidneys and more rapid excretion than the short chain alkyl analogs.[2306]

Symptoms of methyl and ethyl mercury poisoning may occur weeks to months after an acute exposure to toxic concentrations. The symptomatology of acute and chronic poisoning from both compounds is similar; including numbness and tingling of the lips or hands and feet, ataxia, disturbances of speech, concentric constriction of the visual fields, impairment of hearing, and emotional disturbances. With severe intoxication the symptoms are irreversible. Children born to mothers with exposure to large amounts of methyl mercury exhibited mental retardation and also cerebral palsy with convulsions.[2036]

Because so few cases of toxicity have appeared from phenyl mercurials exposure, even to high levels in air over a period of years, it is apparent that these compounds are low in toxicity relative to other forms of mercury. Clinical and experimental evidence suggests that a similar conclusion is applicable to methoxyethyl compounds.[2036]

The Threshold Limit Values (TLV) of 1971[0225] recommended by the American Conference of Governmental Industrial Hygienists for alkyl mercury compounds on the skin is 0.01 mg/m^3, and 0.05 mg/m^3 for all forms of organic mercury compounds except alkyl.

3. OTHER HAZARDS

The flammability of organic mercury compounds is governed by the nature of the organic portion of the molecule and any other materials (solvents, additives, etc.) with which they are associated in commercial products. The danger of liberated mercury or mercury compounds must always be recognized whenever organic mercury compounds are decomposed by heat or fire.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, Transportation

Since all organic mercury compounds are toxic to man in some degree by inhalation, ingestion, or skin contact, great care must be exercised in their handling. Manufacturers instructions for handling and storage should be closely followed. The use of rubber gloves, goggles, a respirator, and full protective clothing is recommended in the handling of these materials over an extended period of time or in large amounts where the likelihood of exceeding the Threshold Limit Value is present. Shipping of these materials should be commensurate with existing federal regulations.[0278]

Disposal/Reuse

Contaminated, degraded, or surplus organic mercury compounds most probably will not be considered for reprocessing because of the cloudly commercial future for these materials. Suspension of government approval of some products containing alkyl mercury and proceedings to cancel federal registration of the 750 uses of mercury pesticides[2138] might have sufficient impact to shut down production facilities and eliminate the market for recycled material:. Any method of safe disposal of these materials must be defined in terms of the recommended maximum concentrations released to the environment. These recommended maximum concentrations are as follows:

Contaminant and Environment	Maximum Recommended Concentration	Basis of Recommendation
Alkylmercury compounds in air	0.0001 mg/M^3/24 hours	0.01 TLV
Alkylmercury compounds in water	0.0005 ppm/24 hours	TLV Ingestion
Other organic mercury compounds in air	0.0005 mg/M^3/24 hours	0.01 TLV
Other organic mercury compounds in water	0.0025 ppm/24 hours	TLV Ingestio-

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Option 1 - Dilute Aqueous Organic Mercury Wastes.[2127] A system for the removal of mercury from plant waste liquors has been developed by the Ventron Corporation. Waste water containing organic mercury compounds is treated with chlorine to convert the organic mercury to inorganic mercury compounds. Then the waste water containing inorganic mercury compounds is fed, along with a 12 percent solution of $NaBH_4$ (in caustic), into a static mixer. The pH is held between 9 and 11. The $NaBH_4$ reduces the mercury compounds, yielding a metallic mercury precipitate and hydrogen gas. Following separation of the gas, which is scrubbed with dilute nitric acid solution to eliminate any mercury vapor, the slurry is passed to a cyclone. There, 80 to 90 percent of the Hg comes out as a sludge. Clarified effluent is then sent to polishing filters where the remaining mercury is removed.

Option 2 - Dilute Organic Mercury in Organic Wastes and Concentrated Organic Mercury Wastes. Organic materials containing mercury are best disposed of by incineration with recovery of the metallic mercury using water scrubbers, mist eliminators, specially prepared activated-carbon beds or a combination of the above.[0533] Incinerators must be provided with adequate means of removing other combustion products derived from the organic portion of the molecules from the gas stream such as chlorine, hydrogen chloride, sulfur dioxide, NO_x and other compounds considered to be pollutants.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

It is anticipated that dilute aqueous organomercury-containing wastes can be adequately treated at the site of waste generation using Option 1 or a similar method. Disposal of dilute and concentrated organic wastes containing organic mercury compounds may also be handled by manufacturers and some users at the site of waste generation provided the organization in question has properly designed and operated incineration facilities. However, it is likely that many sources of organic mercury-containing wastes will not be able to support the specialized incineration and recovery facilities needed for their disposal. Therefore, it is recommended that provision be made at appropriate National Disposal Sites for disposal of organomercury wastes by some variation of Option 2.

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name ORGANIC MERCURY COMPOUNDS

IUC Name ______

Common Names PHENYL MERCURIC ACETATE

Structural Formula

$C_6H_5HgO_2C_2H_3$

Molecular Wt. 336.75 Melting Pt.(1) 149 C Boiling Pt. ______

Density (Condensed) ______ @ ______ ______ Density (gas) ______ @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

______ @ ______ ______ @ ______ ______ @ ______

Flash Point ______ Autoignition Temp. ______

Flammability Limits in Air (wt %) Lower ______ Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility

Cold Water Slightly soluble Hot Water Slightly soluble Ethanol soluble

Others: Soluble in glacial acetic acid, acetic acid, benzene

Acid, Base Properties ______

Highly Reactive with Dangerous when heated to decomposition

Compatible with ______

Shipped in ______

ICC Classification ______ Coast Guard Classification ______

Comments High mammalian toxicity,(2) oral LD_{50} for rats 72 mg/Kg(2)

References (1) 1570
(2) 0637

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Organic Mercury

IUC Name Dimethyl Mercury

Common Names Methyl Mercury

Structural Formula

$Hg(CH_3)_2$

Molecular Wt. 230.66 Melting Pt. -154 C Boiling Pt.(1) 96 C

Density(1) (Condensed) 3.069 @ 20/4 C Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility (1)

Cold Water insoluable Hot Water Ethanol soluble

Others: ether

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Coast Guard Classification

Comments

References (1) 1570

PROFILE REPORT

Phosphorus Pentasulfide (335)

1. GENERAL

Phosphorus pentasulfide is one of only four phosphorus-sulfur compositions which are definite chemical entities. It is the largest volume phosphorus sulfide produced. Phosphorus pentasulfide (chemical name, tetraphosphorus decasulfide) is referenced in the literature as P_2S_5, however, the yellow-green crystals manufactured in bulk quantity exist in the P_4S_{10} state.[1620,1433,2209]

Modern commercial preparation of phosphorus pentasulfide is carried out by reacting white phosphorus and elemental sulfur continuously at about 350 C. It is also made in commercial quantities by heating elemental sulfur with red phosphorus in a batch process. When the molten phosphorus pentasulfide is cooled properly it consists almost completely of crystalline P_4S_{10}.[1620] The crystals are then purified by washing with carbon disulfide to remove small percentages of phosphorus sesquisulfide and free sulfur. In 1971 approximately 70,000 tons of phosphorus pentasulfide was produced by these three major manufacturers:

Monsanto Company: Industrial Chemicals Unit,
Sauget, Illinois

Hooker Chemical Co.: Industrial Chemicals Division
Niagara Falls, New York

Stouffer Chemical Co.: Specialty Chemicals Division
Morrisville, Pennsylvania

This represents almost a 100 percent increase in productin since 1965 when U.S. production was marked at 34,000 tons.

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The major impetus behind the growth of phosphorus pentasulfide has been its continued demand in the expanding manufacture of organic phosporus compounds used as plasticizers and in insecticide production. A more recent and expanding use is in the production of thio-phosphate esters used in gasoline and oil additives.[1433,1620,2200] The largest single-volume items produced are the dithiophosphates used in the manufacture of parathion and methyl parathion and oil additive zinc dithiophosphate. Extensive government pollution control legislation could materially affect the use of parathion, methyl paration and zinc dithiophosphate which, in turn, would reduce the production of phosphorus pentasulfide drastically.

Sources of Waste

The main sources of phosphorus pentasulfide waste may include: (1) the manufacturer of the chemicals; (2) pesticide formulators; (3) oil additive producers; (4) storage facilities and (5) shipping containers.

In general, the only wastes possible are the concentrated crystalline pentasulfide material. Consequently, unused or contaminated materials left in shipping containers or spillage constitute the major sources of concentrated waste.

There are essentially no diluted wastes associated with phosphorus pentachloride due to its rapid decomposition upon contact with water. The following equation typifies the reaction of phosphorus pentasulfide with water:

$$P_4S_{10} + 16H_2O \longrightarrow 4H_3PO_4 + 10H_2S$$

Physical and Chemical Properties

Phosphorus pentasulfide is a gray to yellow-green solid with a specific gravity of 2.03 (water = 1.0), a melting point of 296 C and a boiling point of 513 C. It exists as a dry non-corrosive powder which is flammable.[1620, 2209,2217] Detailed physical and chemical properties are contained in the attached Hazardous Waste Worksheet.

2. TOXICOLOGY

Phosphorus pentasulfide is only a mild irritant in its pure solid state. It can cause slight skin irritation upon contact and serious irritation to the eyes and mucous membranes. Effects of inhalation or ingestion range from minor irritation and coughing, to respiratory failure.[0766,2217] The American Conference of Governmental Industrial Hygenists recommends a Threshold Limit Value (TLV) of 1.0 mg/m^3 of air.

The major hazard associated with phosphorus pentasulfide is a result of the rapid decomposition of P_4S_{10} upon contact with moisture into toxic and flammable hydrogen sulfide and phosphoric acid.

$$P_4S_{10} + 16H_2O \longrightarrow 4H_3PO_4 + H_2S$$

The ACGIH recommended TLV for H_2S is 10 ppm or 15 mg/m^3. At high concentrations it has a paralyzing effect of the olfactory nerves and therefore cannot be detected by odor. Phosphorus pentasulfide is also extremely dangerous when heated. The fumes emitted are phosphorus pentoxide which has a recommended TLV of 0.1 mg/m^3 of air, and oxides of sulfur which are extermely toxic (TLV of 5 ppm for SO_2).

Water pollution hazards associated with pure phosphorus pentasulfide are negligible because of its rapid decomposition.[0766,2209,2217]

3. OTHER HAZARDS

Phosphorus pentasulfide is ignitable by friction and by static and struck sparks at room temperature and will spontaneously ignite at temperature near its melting point of 280 C. At low temperatures it burns slowly unless it is dispersed in air and then burns rapidly. The dust of pentasulfide presents an explosion problem. In addition, flammable hydrogen sulfide gas is liberated in the presence of moisture. Phosphorus pentasulfide has also been kmwon to react with acids and oxidizing agents to yield the same products as the reaction with water.[2209]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage and Transportation

Phosphorus pentasulfide must be handled with care to avoid the generation of hydrogen sulfide vapors, the hazards of dust explosion and hazards of spontaneous ignition. However, since phosphorus pentasulfide is not corrosive it does not require any special materials of construction in its production. It must, however, be stored in a cool, dry, non-combustible ventilated area separated from other combustibles, acids or oxidizing materials. Equipment must be grounded to avoid friction sparks. Inert nitrogen is recommended as the best protection against explosion, toxicity and hydrolysis dangers.[2217] Personnel should have chemical safety goggles, rubber gloves and rubber shoes to prevent contact with the skin. Also self-contained breathing apparatus or externally supplied air masks should be located nearby in the event of H_2S emission.

Phosphorus pentasulfide is not classified as a dangerous article by the ICC for the purpose of transportation. The usual shipping containers are fiber or steel drums and aluminum tote bins. Most manufacturers and users who utilize tote bins design their equipment so that the tote bin is filled, sealed shipped and emptied without ever being open to the atmosphere. This eliminates most of the hazards associated with the chemical.[2201]

Disposal/Reuse

Contaminated or degraded phosphorus pentasulfide is usually not considered for reprocessing, although manufacturers would normally accept it for disposal. As mentioned in the previous section, manufacturers and users minimize their waste material by using equipment which minimizes contact with the atmosphere.

Safe disposal techniques are normally based on the TLV for phosphoric acid which is 0.01 mg/m^3/24 hours. Careful consideration must also be given to the decomposition product hydrogen sulfide which has recommended maximum concentration of 10 ppm/8 hour period. (See Profile Report on Hydrogen Sulfide (221) for more detail on hydrogen sulfide.)

5. EVALUATION OF CURRENT AND NEAR FUTURE RECOVERY PROCESSES

Since phosphorus pentasulfide is a powdered solid with a very low vapor pressure it does not present an air pollution problem. The only source of waste is the solid scrap material accumulated from spills in manufacturing or loading.

Option No. 1 - Decomposition with Water

Several manufacturers of phosphorus pentasulfide recommend dousing small quantities of the chemical with copious amounts of water, while taking precautions to keep hydrogen sulfide generation at a low level.[2201,2204] Large volumes of water keep the decomposition temperature low,thereby reducing the H_2S emission. The aqueous decomposition product (phosphoric acid) can then be treated by standard industrial wastewater treatment techniques (e.g., neutralization).[2201,2217]

Option No 2. - Burial

Phosphorus pentasulfide can be safely buried in a sanitary landfill disposal sight. This essentially is a slow oxidation process which must be carefully done to minimize the evolution of hazardous hydrogen sulfide. Small quantities may be adequately handled in this manner.[2204,2209]

Option No. 3 - Incineration

Phosphorus pentasulfide can be incinerated to yield phosphorus pentoxide (P_2O_5) and sulfur dioxide (SO_2). Large quantities of waste material should be disposed of by incineration only where the combustion equipment is capable of removing the combustion products from the exhaust gas stream.[2217,2209]

Phosphorus pentasulfide rapidly decomposes upon contact with water into phosphoric acid and gaseous hydrogen sulfide. Therefore, it does not present a water pollution hazard in its pure chemical state. Standard neutralization techniques and dilution of the resultant stream are the simplest and cheapest method of disposal. The danger is thereby limited to the increase in phosphate concentration which could possibly lead to an increased rate of water eutrophication.

6. APPLICABILITY TO NATIONAL DISPOSAL SITE

It is anticipated that disposal systems to handle phosphorus pentasulfide waste material will not be required at National Disposal Sites. All waste material generated is easily decomposed, neutralized or recycled at the plant operation level.

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2216. Personal Communication. L. Cavender, FMC Inc. to W. L. Niro, TRW Systems, July 31, 1972. Phosphorus trichloride and phosphorus oxychloride waste disposal.

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Phosphorus Pentasulfide

IUC Name Tetrophosphorus Decasulfide

Common Names Thiophosphoric Anhydride

Structural Formula

P_4S_{10}

Molecular Wt. 444.56 (1) Melting Pt. 286 C (1) Boiling Pt. 513 C (2)

Density (Condensed) 2.03 @ 20 C (1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

1 mm Hg @ 300 C @ @

Flash Point Autoignition Temp. 260 290 C (dust)
275 C (liquid)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower 0.050 oz/cuft (200 mesh dust in air) Upper

Solubility

Cold Water Decomposes (2) Hot Water Ethanol

Others:

Acid, Base Properties dry powder noncorrosive

Highly Reactive with water to form toxic, corrosive, flammable hydrogen sulfide. Reactive with acids and oxidizing agents also.

Compatible with mild steel.

Shipped in fiber and steel drums or aluminum tote bins.

ICC Classification Coast Guard Classification

Comments A yellow green powder which will: (1) react with water to form hydrogen sulfide; (2) ignite by spark or friction; (3) explode when dispersed as a dust; (4) decomposes into toxic and corrosive sulfur dioxide and phosphorus pentoxide.

References (1) 2209, 2217
(2) 1620

PROFILE REPORTS ON
HALOGENATED PHOSPHORUS COMPOUNDS
PHOSPHORUS CHLORIDES

Phosphorus Trichloride (336), Phosphorus Pentachloride (334) Phosphorus Oxychloride (333)

1. GENERAL

Introduction

Phosphorus halides were discovered and investigated by Gay Lussac and Thenard in France at the beginning of the 19th century.[1620] The best known and most studied compounds are the trihalides, pentahalides and oxyhalides. The phosphorus halides of commercial importance today are phosphorus trichloride, PCl_3; phosphorus pentachloride, PCl_5; and phosphorus oxychloride, $POCl_3$.[1433] All are used extensively in manufacturing organic phosphorus compounds and in chlorinating organic compounds to give acid chlorides.[1433,1620] Demand for the phosphorus chlorides has been steady over the past five years with phosphorus trichloride fluctuating between 50-55,000 tons per year and phosphorus oxychloride varying from 31-35,000 tons per year.[1751,2202] Production figures for phosphorus pentachloride are unavailable. The major United States producer is Hooker Chemical Co., Industrial Chemicals Division in Niagara Falls, New York.[2201] Future market importance and production will be affected by possible regulations on chlorinated pesticides and gasoline additives which constitute another major outlet for the phosphorus chlorides.[2202]

Manufacture

Phosphorus Trichloride: Phosphorus trichloride is manufactured by a direct union of liquid red or white phosphorus and gaseous chlorine according to the reaction:

$$2P + 3Cl_2 \longrightarrow 2PCl_3$$

Gaseous chlorine is blown into a reactor containing the liquid phosphorus and a precharge of phosphorus trichloride. The highly exothermic reaction is controlled by either refluxing cooled phosphorus trichloride or by adding carbon disulfide as an inhibitor. Crude phosphorus trichloride is then fractionally distilled to remove traces of oxychloride and organic chloride compounds.[1620,1433,2200] All reaction vessels are closed to the atmosphere and vents are equipped with refrigerated condensers to eliminate any discharge of trichloride vapors. The final vapor stream is water scrubbed to remove any final traces of trichloride.[2216] Production over the last five years was approximately 50,000 tons per year.

Phosphorus Pentachloride: Phosphorus pentachloride is manufactured either batchwise or continuously by contacting phosphorus trichloride with gaseous chlorine according to the following reaction:

$$PCl_3 + Cl_2 \longrightarrow PCl_5$$

In the batch reaction phosphorus trichloride is first dissolved in carbon tetrachloride. Chlorine is then blown over the surface of the solution causing phosphorus pentachloride crystals to form. The crystals are removed, filtered, dried (carbon tetrachloride strips off and is returned to the reaction vessel in this step) and sent to storage. The continuous reaction process produces phosphorus pentachloride by passing chlorine gas countercurrent to the phosphorus trichloride and collecting the resultant crystals at the bottom of the reaction tower.[1433,1620] Yearly United States production figures are not available in the literature and could not be ascertained during our investigation. The major producer of the pentachloride is Hooker Chemical Company in Niagara Falls, New York. Other previous manufacturers who have not continued their production are Monsanto Company and FMC Incorporated.[2202]

Phosphorus Oxychloride: Phosphorus oxychloride (also called phosphoryl chloride) is most commonly manufactured by oxidizing phosphorus trichloride with pure oxygen or air.

$$2PCl_3 + O_2 \longrightarrow 2POCl_3$$

Oxygen bubbled through liquid phosphorus trichloride at 20 - 50 C will result in a 95-97 percent complete reaction, so that only 3-5 percent trichloride remains in the oxychloride. Another well-known method of phosphorus oxychloride manufacture consists of a reaction between phosphorus pentachloride and phosphorus pentoxide:

$$P_4O_{10} + 6PCl_5 \longrightarrow 10POCl_3$$

The two solids are slowly heated and mixed until the liquid oxychloride is formed. Pure oxychloride is distilled off, cooled and sent to storage.[1433,1620] Yearly production in the United States has varied between 31,000 and 35,000 tons over the past five years with no great changes expected in the future.[1506,2202]

The bulk of the phosphorus chlorides are manufactured by four major United States corporations:[1506,2201,1411]

Monsanto Industrial Chemicals Company, Sauget, Illinois

FMC Incorporated, Organic Chemicals Division
Nitro, West Virginia

Hooker Chemical Co., Industrial Chemicals Division
Niagara Falls, New York

Stauffer Chemical Co., Specialty Chemicals Division
Morrisville, Pennsylvania

Uses

All of the phosphorus chlorides are used in the manufacture of organic-phosphorus compounds. Phosphorus trichloride is used primarily as a chlorinating agent in the manufacture of organic acid chlorides. When reacted with alcohols or phenols a phosphite or phosphate ester is produced. Certain end use products are dyestuffs, organic antioxidants, vinyl stabilizers and plasticizers. Phosphorus pentachloride is similarly used as a chlorinating agent and catalyst in organic synthesis. The pentachloride is essentially a more reactive chlorinating agent than the trichloride. It recently has found additional uses as a catalyst in lubricant additive production and insecticide manufacture. Phosphorus oxychloride is one of the phosphorus-containing intermediates that may become of greater importance with an expanding plastics industry. The major portion of oxychloride produced is presently used in organic synthesis; chiefly in manufacturing phosphate esters (tricresyl phosphate, a common plasticizer). The second most important use for oxychloride is in production of cresyl diphenyl phosphate and triisopropyl phosphite, gasoline additives.[1433, 1620,2200,1411,0636,1501]

More recent uses include the organic phosphorus insecticides, parathion and methyl parathion. Other less known but increasing uses include fire resistant hydraulic fluids and flame retardants.[1433,2206]

Sources and Types of Waste

The main source of phosphorus trichloride, pentachloride and oxychloride waste is the material remaining in shipping containers after emptying. That is, the thin film left in drums and the "heel" left in tank cars and tank trucks. There are essentially no production wastes generated since all production equipment is either closed loop or equipped with refrigerated condensers to eliminate chemical emissions to the atmosphere. Storage tanks are nitrogen blanketed, pumps utilize mechanical seals and drums are purged of air before sealing.

There are no aqueous dilute wastes. Since all three compounds rapidly decompose upon contact with water, the only source of aqueous pollution is the decomposition products, namely, hydrochloric and phosphoric acids. The concentrated wastes, however, include the unused or contaminated materials left in emptied containers and any "off-spec" production material.

Physical/Chemical Properties

Phosphrous trichloride is a fuming liquid that boils at 76 C, phosphorus pentachloride is a solid that sublimes at 148 C, while the oxychloride is a fuming liquid that boils at 107 C. Each has a specific gravity of approximately 1.6 (water = 1.0). They react violently (highly exothermic) when contacted with moisture and usually produce hydrogen chloride gas, steam, phosphoric acid and hydrochloric acid. Detailed physical and chemical properties of all three chlorinated phosphorous compounds can be found on the attached worksheets.

2. TOXICOLOGY

Phosphorus trichloride and phosphorus pentachloride are similar in toxicity in that a small amount in the atmosphere will cause prompt irritation of the eyes, nose, throat and lungs (all mucous membrane). Suffocation, bronchitis, edema and lung inflammation may all result from extended exposures. Severe exposure in a concentration of 600 ppm is lethal within a few minutes. The vapors are also irritating to the skin, while the liquid (or solid) can cause severe skin burns immediately upon contact.[1897,2205,2208] The American Conference of Governmental Industrial Hygienists 1971 recommends Threshold Limit Values (TLV) for phsophorus trichloride in air at 0.5 ppm or 3 mg/m^3; and for phosphorus pentachloride in air at 1 mg/m^3.[0025,0636]

Phosphorus oxycloride causes similar effects to the trichloride and pentachloride in that its vapors are very irritating to all mucous membranes and to the lungs. The liquid itself can cause severe burns of the skin. Inhalation symptoms range from coughing to delayed wheezing due to bronchial irritation or pulmonary edema.[2206,2207] The AIGIH recommended TLV for phosphorus oxychloride in air is 0.1 ppm.[0025]

There is no aquatic toxicity possible from the three pure chlorinated phosphorus compounds. All readily decompose upon contact with water into hydrochloric acid and phosphoric acid. The level above which fish are affected by aqueous phosphoric acid is 0.1-10 ppm. The level above which aqueous hydrochloric acid will affect fish is 1.0 ppm.

3. OTHER HAZARDS

Phosphorus trichloride and phosphorus pentachloride by themselves are neither flammable nor explosive. However, each reacts violently with small amounts of water liberating heat, spontaneously flammable phosphine gas, hydrogen chloride, phosphorus acid and even free spontaneously flammable phosphorus. They will also react violently with slight moisture, oxidizing agents, fibrous organic matter and alkalies. The hydrochloric and phosphoric acids generated on reaction with water can attack most metals to form hydrogen gas which is both highly flammable and explosive.[1897,2205,2208]

Phosphorus oxychloride can be classified along with the other chlorinated phsophorus compounds in that it is neither flammable nor explosive. It is, however, much more corrosive in its pure state than either phosphorus trichloride or phosphorus pentachloride. Phosphorous oxychloride reacts violently with water giving off hydrogen chloride gas and steam. One gallon of water added to an excess of Phosphorus oxychloride will liberate in excess of 100 cu ft of hydrogen chloride.[1433] The reaction products, hydrochloric and phosphoric acids, can react with metals to form highly flammable hydrogen gas. Oxychloride has also displayed violent reactions with alkalies and fibrous organic matter.[2206]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage and Transportation

Phosphorus trichloride, phosphorus pentachloride and phosphorus oxychloride are all toxic by inhalation or skin contact. It is extremely irritating to mucous membranes and the lungs. Body moisture is sufficient to decompose them into acids which will cause severe acid burns. Full protective clothing, including gas tight safety goggles, face shields, rubber shoes, rubber gloves and rubber apron, are required in their handling. In cases of accidental contact all contaminated clothing should be removed at once and exposed skin washed thoroughly with large quantities of water. To avoid vapor inhalation an acid-gas canister type respirator is recommended. In the event of severe exposure by inhalation, pure oxygen should be administered for at least 30 minutes.[1897,2205,2206,2207,2208]

Phosphorus trichloride and oxychloride are loaded into drums, tank cars and tank trucks at stations equipped with fume-scrubbing devices to prevent harmful vapors from reaching either the operator or the atmosphere.[2203]

Storage of small quantities of all three chemicals should be in cool, dry well ventilated areas. Although each has a relatively high boiling point they are all very reactive with moisture in the atmosphere. Because of its corrosive nature, lead-lined, ceramic-lined or nickel-lined steel drums should be used and kept sealed from potential contact with any moisture. Large quantities are usually stored in nickel- or lead-lined steel tanks and blanketed with nitrogen. Since phosphorus pentachloride is a solid it may be stored in ordinary steel carboys or steel drums; however, the drums must be sealed tightly to avoid any contact of the pentachloride with moisture. 1897,2207

Phosphorus trichloride and phosphorus oxychloride are classified by the U. S. Department of Transportation (DOT) as corrosive liquids. As such they must be packaged and shipped in accordance with Title 49 of the Code of Federal Regulations, Section 73.271. Phosphorus pentachloride is classified by DOT as a flammable solid and must be packaged and shipped according to Title 49 of the Code of Federal Regulations, Section 73.191.[0278]

Additional detailed information on the safe handling, storage and shipping of phosphorus trichloride and phsophorus oxychloride may be obtained by referring to Chemical Safety Data Sheets SD-27 and SD-26 published by the Manufacturing Chemists Association.

Disposal/Reuse

Contaminated lots of phosphorus trichloride, oxychloride and pentachloride are usually sold as contaminated or "off-spec" material. Manufacturers generally recycle and repurify any material if found to be contaminated or off-specification.[2204] The current method for disposing of small quantities of the phosphorus chlorides is to douse with copious amounts of water. Every manufacturer contacted utilizes water to dispose of small quantities of waste material.[2201,2203,2204,2216] Monsanto Industrial Chemical Division in Sauget, Illinois disposes of larger quantities (a heel from a tank car) in the following manner: They slowly add phosphoric acid to the material and then very slowly neutralize the entire mass with a sodium carbonate solution. The neutralized mass is then sewered to the waste treatment plant.[2204] The only other method feasible for disposal of large quantities is to react the phosphorus chloride slowly with copious amounts of water and neutralize the resultant acids with caustic, limestone or other basic material.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL/RECOVERY PROCESSES

Generally, phosphorus trichloride, phosphorus pentachloride and phosphorus oxychloride do not present serious pollution problems to the chemical industry because of their low volatility, easy recovery and simple decomposition as discussed below.

Removal From Air

Option No. 1 - Refrigerated Condensation. When present in sufficiently high concentrations, phosphorus trichloride and phosphorus oxychloride has been removed from vapor streams by refrigerated condensation. FMC Incorporated employs such a system in its Nitro, West Virginia production facility to control phosphorus trichloride and oxychloride emissions from its reaction equipment.[2216] The bulk of vapor is condensed and collected and trace material is removed by a final water scrubbing system.

Option No. 2 - Decomposition With Water. Most vapor streams resulting from loading operations are decomposed by a reaction of the particular phosphorus chloride compound with large volumes of water. Since phosphorus trichloride, phosphorus oxychloride, and phosphorus pentachloride rapidly decompose to hydrochloric and phsophoric acids upon contact with water, it is the cheapest most efficient method utilized. The resultant dilute acid stream is easily neutralized with caustic, soda ash, or limestone and sent to the plant sewage wastewater stream.[2201,2204,2216]

Removal From Water

All three chemicals, the trichloride, the pentachloride and the oxychloride of phsophorus readily decompose into phosphoric and hydrochloric acids upon contact with water. Consequently they do not present a water pollution hazard in their pure state. Standard neutralization techniques and dilution of the resultant stream is the simplest and cheapest technique. The danger is thereby limited to the increase of phosphate concentration leading to a possibly increased rate of eutrophication.

Disposal/Recovery of Concentrated Wastes

The major manufacturers of phosphorus pentachloride and phosphorus oxychloride admit that they have never had the problem of disposing of large quantities of concentrated waste material.[2201,2204,2216] The major sources of concentrated wastes are spills in loading, material left in emptied containers and "heels" left in tank cars or tank trucks.

Option No. 1 - Recycle. Waste material is easily recycled to the plant production system. Drums, tank cars and tank trucks can be drained or vacuumed to holding tanks, returned to the production process and purified. FMC Inc., Monsanto and Hooker Chemical Co. said all material returned to them is handled in this manner.[2201,2204,2216]

Option No. 2 - Decomposition. All three phosphorus compounds decompose readily in water. Therefore, flushing with water is an extremely effective and economical method of disposal. Under controlled conditions, utilizing large amounts of water, phosphorus trichloride, pentachloride and oxychloride are reduced to phosphoric and hydrochloric acids which are easily neutralized.

Option No. 3 - Chemical Degradation. Monsanto Industrial Chemicals Co. in Sauget, Illinois occasionally uses a degradation technique to scrap phosphorus trichloride and phosphorus oxychloride. The plant practice is to slowly add phosphoric acid to the material and then very slowly neutralize the mass with a sodium carbonate solution. The neutralized mass is then sewered to the waste treatment plant. This proves to be an adequate disposal technique for larger quantities of waste material.

6. APPLICABILITY TO NATIONAL DISPOSAL

It is anticipated that disposal systems to handle concentrated or dilute phosphorus trichloride, phosphorus pentachloride and phosphorus oxychloride waste material will not be required at National Disposal Sites. All waste material generated is easily decomposed, neutralized or recycled at the plant operation level.

In the event large quantities must be disposed (e.g., tank car quantity) several manufacturers said that they would recycle and reuse the "waste" material. Even without recycling, decomposition with large volumes of water would prove to be the most efficient method of disposal.

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Phosphorus Oxychloride

IUC Name

Common Names Phosphoryl Chloride

Structural Formula

$POCl_3$

Molecular Wt. 153.35(1) Melting Pt. 1.22 C(1) Boiling Pt. 107.2

Density (Condensed) 1.675 @ 20 C/4 C Density (gas) 5.30 @ 0 C
(air = 1.0)

Vapor Pressure (recommended 55 C and 20 C)

40 mm Hg @ 27.3 C 100 mm Hg @ 47.4 C 400 mm Hg @ 8.43 C

Flash Point none Autoignition Temp. none

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility (1)

Cold Water Decomposes Hot Water Decomposes Ethanol Decomposes

Others: Carbon tertrachloride

Acid, Base Properties (2) Very corrosive to most common metals except nickel and lead

Highly Reactive with water, alkalies or fibrous organic matter.

Compatible with nickel and lead

Shipped in nickel lined tank cars and steel drums; 316 stainless steel tank cars (3)

ICC Classification Corrosive liquid Coast Guard Classification Corrosive liquid

Comments A clear, colorless fuming liquid that hydrolyzed into phosphoric and hydrochloric acids. It volitizes quickly upon contact with water giving off hydrogen chloride gas. Acids formed can react with metals to give off highly flammable hydrogen gas.

References (1) 2206, 1570
(2) 2207
(3) 2216

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HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Phosphorus Pentachloride

IUC Name

Common Names same

Structural Formula

PCl_5

Molecular Wt. 208.3(1)   Melting Pt. 148 C under pressure(1)   Sublimes at 160 C(1)

Density (Condensed) 1.6 @ 20 C/4 C   Density (gas) 4.65 g/l @ 296 C

Vapor Pressure (recommended 55 C and 20 C)

1 mm Hg @ 55.5 C(2)   10 mm Hg @ 83.2 C   100 mm Hg @ 117 C

Flash Point   Autoignition Temp.

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water Decomposes   Hot Water   Ethanol

Others: Carbon tetrachloride, Carbon disulfide, Benzoyl chloride

Acid, Base Properties not corrosive per se--upon reaction with water hydrochloric and phosphoric acids are created.

Highly Reactive with water (moisture) to form toxic and corrosive fumes--potentially explosive if phosphine is formed.

Compatible with non-corrosive materials (e.g., nickel, 316 stainless steel, lead).

Shipped in plastic lined steel drums or carboys.

ICC Classification flammable solid   Coast Guard Classification inflammable solid

Comments Decomposes upon contact with water or heat into hydrogen chloride, phosphorus oxides, phosphorus oxychlorides; flammable phosphine possible. Pentachloride is a yellow white crystalline substance extremely more reactive than phosphorus trichloride.(3)

References (1) 1570, 2208
(2) 1673
(3) 0766

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Phosphorus Trichloride

IUC Name

Common Names Phosphorus Chloride

Structural Formula

PCl_3

Molecular Wt. 137.35(1) Melting Pt. -118.5 C(1) Boiling Pt. 75.5 C(1)

Density (Condensed) 1.575 (ref = water) @ 20/4 C(1) Density (gas) 4.75 (air = 1.0) @ 0 C(1)

Vapor Pressure (recommended 55 C and 20 C)

400 mm Hg @ 56.9 C-(1) 100 mm Hg @ 21 C-(1) @

Flash Point Nonflammable-(2) Autoignition Temp. none

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility (1)

Cold Water Decomposes Hot Water Decomposes Ethanol Soluble

Others: Chloroform, Ether, Benzene, Carbon Disulfide, Carbon Tetrachloride

Acid, Base Properties Corrosive to most metals except nickel and lead(2)

Highly Reactive with water and aqueous solutions, oxidizing agents, fibrous organic matter, alkalies.

Compatible with nickel, lead, 316 stainless steel

Shipped in Carbon steel tank cars, lead or nickel lined steel drums

ICC Classification Corrosive liquid Coast Guard Classification Corrosive liquid

Comments Colorless fuming liquid with pungent, irritating odor resembling that of hydrochloric acid. Contact with water decomposes PCl_3 into hydrochloric and phospheric acid.(3)

References (1) 2205, 1570
(2) 1897
(3) 2216

PROFILE REPORT

Picric Acid (Trinitrophenol-Liquid)(338)

1. GENERAL

Picric acid or 2, 4, 6-trinitrophenol is manufactured as bright yellow crystals, which exist in two polymorphic forms. It was first used as a yellow dye. About 1885, military use as an explosive charge in artillery and motor shells commenced. Picric acid was the first high explosive used for meltloading. It was used widely until the beginning of this century, when it was replaced with TNT. Picric acid is used today in the United States chiefly for the manufacture of Explosive D, ammonium picrate, and in medicine and analytical chemistry.

Since it is a poly-substituted phenol, picric acid is chemically active, although less so than phenol. It decomposes carbonates and reacts with hydroxides to form picrates. Many of the picrates are more sensitive to explosion than picric acid. For military use it is stored dry, but when wet with 10 percent water picric acid may be shipped by common carrier in a maximum quantity of 16 oz per outside package. Since this Profile Report covers only wet or liquid picric acid, the military uses of picric acid will not be considered further.[1147]

Picric acid is manufactured by a number of processes. Direct nitration of phenol is not practical because of the violence of the reaction and consequent low yields. Phenol and sulfuric acid react to form ortho and para-phenol sulfonic acid which can be nitrated to picric acid. Another manufacturing process involves the conversion of dinitrochlorobenzene into dinitrophenol, with subsequent nitration of the dinitrophenol. A catalytic process for preparation of picric acid from benzene has been used which involves refluxing benzene with nitric acid in the presence of mercuric nitrate. Purification of crude picric acid is effected by washing with cold water, followed by recrystallization from hot water.[0472,1147]

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The physical/chemical properties for picric acid are summarized on the attached worksheet.

2. TOXICOLOGY

Picric acid has a strong staining action on the human skin, but is not as toxic as some of the comparable nitro-compounds. Its dust should not be inhaled, and frequent baths and changes of clothing are prescribed for workers in production and use of picric acid.[1147] The Threshold Limit Value (TLV) for picric acid has been established as 0.1 mg per cubic meter.[0225]

3. OTHER HAZARDS

Picric acid is a high explosive that is so sensitive to friction, heat or impact that it undergoes detonation when subjected to a flame or percussion. It is slightly more sensitive than TNT. The explosion temperature test value for picric acid (322 C) is lower than that of TNT (520 C).

The picrates of lead and zinc are formed by contact of molten picric acid with the appropriate metal, and are sufficiently sensitive to the thermal shock from the melt that they initiate detonation of the picric acid. Other metallic picrates are readily formed and generally contain water of crystallization. Although not as sensitive as lead picrate these picrates are very sensitive to impact when dehydrated. For this reason, formation of the picrates of iron, nickel, zinc, copper, etc. is avoided.[1147]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The sensitivity of picric acid to heat, friction and impact require that all waste streams from its manufacture be treated as described in Section 5. Picric acid, dry, is classed by DOT as an Explosive, Class "A". Special regulations for picric acid wet with 10 percent water permit shipment of 16 oz maximum in an outside container by common carrier including passenger aircraft.[1147]

Recommended maximum concentrations of picric acid in effluent streams released to the environment from waste disposal processes are as follows:

Contaminant and Environment	Maximum Concentration and Point Source Release Rate	Basis for Recommendation
Picric acid released to streams and sewers	None	Danger from accumulation
Picric acid released	0.001 mg/m^3	0.01 TLV

5. EVALUATION OF CURRENT AND NEAR FUTURE PICRIC ACID DISPOSAL PROCESSES

Picric acid in aqueous waste streams or excess picric acid is decomposed by dissolving the material in 25 times its weight of water containing 1 part sodium hydroxide and 21 parts hydrated sodium sulfide. The hydrogen sulfide and ammonia liberated must be absorbed or scrubbed from the vent air.[0474,1147] The solution from the disposal process should be neutralized, and the phenolic material remaining oxidized by chlorine or removed by adsorption on carbon. This disposal technique is considered satisfactory where the quantity of picric acid is too low to make recovery economically attractive, or when the material is contaminated.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

It is anticipated that unit operations capable of disposing of small quantities of picric acid will occasionally be required at National Disposal Sites. The process employed should be the disposal technique discussed in Section 5. Dilute waste streams will continue to be treated at the manufacturing facilities.

7. REFERENCES

0225. American Conference of Government Industrial Hygienists. Threshold limit values for 1971. Occupational Hazards, p. 35-40, Aug. 1971.

0474. Tomlinson, W. R., Jr., revised by O. E. Sheffield. Properties of explosives of military interest. Technical Report No. 1740, Rev. 1, Picatinny Arsenal. Apr. 1958. 348 p.

1147. Department of the Army and the Air Force. Military explosives, TM-9-1910, Washington. Apr. 1958. 336 p.

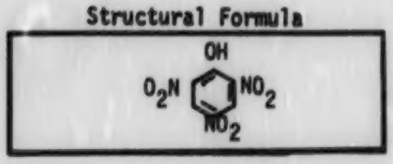
HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Picric Acid

IUC Name 2,4,6-Trinitrophenol

Common Names

Structural Formula



Molecular Wt. 229(1) Melting Pt. 122 C(1) Boiling Pt. 320 C explodes(1)

Density (Condensed) 1.76g/cc @ 23 C (1) Density (gas) ____ @ ____° ____

Vapor Pressure (recommended 55 C and 20 C)

2 torr @ 195 C (1) 50 torr @ 255(1) C ____ @ ____°

Flash Point ____° Autoignition Temp. ____°

Flammability Limits in Air (wt %) Lower ____ Upper ____

Explosive Limits in Air (wt. %) Lower ____ Upper ____

Solubility

Cold Water 1.17g/100g at 20 C(1) Hot Water 7.1g/100g at 100 C(1) Ethanol 6.9g/100g(1)

Others: Benzene 9.6g/100g(1)

Acid, Base Properties Weak acid(1)

Highly Reactive with Bases; forms sensitive metal micretes with lead, zinc, and other base metals.(1)

Compatible with

Shipped in Bottles, wet(1)

ICC Classification Explosive, Class A(1) Coast Guard Classification Explosive, Class A(1)

Comments Special regulation for common carrier(1)

References (1) 0474

PROFILE REPORT

Tear Gas, Irritant (CS) (423)

1. GENERAL

Irritant tear gas (CS) or 2-chlorobenzylidene malononitrile is employed as a riot control agent. As an aerosol it is a powerful irritant to the eyes and upper respiratory organs. CS is a white crystalline substance that is prepared by reacting 2-chlorobenzaldehyde with malonic acid nitrile.[0778]

The physical/chemical properties of CS are summarized in the attached worksheet.

2. TOXICOLOGY

Individuals exposed to CS develop a severe conjunctivitis which is accompanied by a burning sensation, great pain, and a flow of tears. With the exception of the conjunctivitis, the effects last only 5 to 15 minutes. The intensity of conjunctivitis decreases after 25 to 30 minutes. Other symptoms of CS intoxication are copious nasal discharge and flow of saliva, as well as irritation of the nose. Headache, nausea and lethargy are non-specific and do not occur in all cases. With longer exposure or high concentrations, erythemata and blisters develop.

The maximum exposure time that various concentrations can be tolerated are listed below.

Exposure Time	Maximum Concentration, mg/M^3
1 minute	5[0778]
12 seconds	10[0778]
6-9 seconds	34[0778]
Incapacity to minimum function	1-5[0778]
Threshold Limit Value (TLV)	0.4[0225]

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3. OTHER HAZARDS

When CS is exposed to moisture, hydrolysis takes place. The products of hydrolysis are 2-chlorobenzaldehyde and malonic acid nitrile, a highly toxic material.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Personnel handling, manufacturing, using or disposing of CS must have available gas masks of a design approved by U.S. Bureau of Mines for CS service with approved cannisters for CS. All equipment must be adequately designed to prevent release of CS to the atmosphere. CS is shipped under DOT regulation for a Poison, Class C.[0766] The recommended maximum CS released to the atmosphere should not exceed 0.004 mg per cubic meter which is 0.01 of the TLV.

5. EVALUATION OF CURRENT AND NEAR FUTURE CS DISPOSAL PROCESSES

The processes for treatment of CS waste are briefly described in the following paragraphs. The processes described are for handling concentrated CS, but these methods with slight modification can be used to decontaminate an area contaminated with CS.

Option 1 - Hydrolysis Followed by Incineration

CS is relatively resistant to hydrolysis by pure water. However, in a 95 percent ethanol and 5 percent water solution at 30 C, 99 percent of the CS present is hydrolyzed. CS waste may be treated by dissolving the material in 95 percent ethanol, allowing the mixture to stand overnight, and then destroying the hydrolysis products and residual CS by incineration followed by a caustic scrubber. The products of hydrolysis are 2-chlorobenzaldehyde and malonic acid nitrile.

Option 2 - Hypochlorite Treatment

Oxidizing agents attack the ethylenic linkage in the side chain to form various products. If hypochlorite is used in an aqueous solution with CS, an epoxide is formed at the double bond.[0778] The treatment of CS with a hypochlorite solution will detoxify the CS, but a new material is formed which requires disposal. Except for decontamination operations, this process is not recommended.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

It is anticipated that small quantities of packaged CS will be received at National Disposal Sites from police agencies and other groups involved in riot control. It is recommended that National Disposal Sites have unit operations capable of performing the processes outlined in Option 1.

7. REFERENCES

0225. American Conference of Government Industrial Hygienist. Threshold Limit Values for 1971. Occupational Hazards, Aug. 1971. p. 35-40.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed., New York, Reinhold Publishing Corp. 1968. 1,251 p.

0778. Franke, Siegfried. Manual of military chemistry, chemistry of chemical warfare agents, V 1. Deutscher Militarverlag, 1967, East Berlin. Translated by Assistant Chief of Staff for Intelligence, Department of the Army, AD849866, Washington. 1968. 542 p.

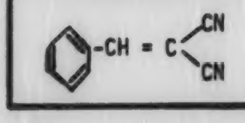
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Tear gas, irritant(CS)

IUC Name 2-chlorobenzylidene malononitrile

Common Names Tear gas

Structural Formula



Molecular Wt. 153 (1) Melting Pt. 95 C (1) Boiling Pt. 310 to 315 C (1)

Density (Condensed) @ ° Density (gas) @ °

Vapor Pressure (recommended 55 C and 20 C)

@ ° @ ° @ °

Flash Point ° Autoignition Temp. °

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water soluble (1) Hot Water soluble (1) Ethanol soluble (1)

Others: soluble - gasoline, acetone (1)

Acid, Base Properties

Highly Reactive with Oxidizing agents (1)

Compatible with

Shipped in

ICC Classification Poison, Class C (1) Coast Guard Classification Poison, Class C (1)

Comments

References (1) 0778

PROFILE REPORTS

Thallium (430) and Thallium Sulfate (431)

1. GENERAL

Production

There is one producer of thallium and thallium sulfate (Tl_2SO_4) in the United States, the American Smelting and Refining Company, Denver, Colorado.[1433, 2179, 2239, 2182] Its thallium department "operates on a very intermittent basis, having produced thallium in five short campaigns over the past twenty years. The department is not now in operation and is not scheduled for the foreseeable future."[2242]

Thallium is produced as a byproduct of the production of cadmium, which, in turn is produced as a byproduct of the production of zinc. The zinc dross remaining from the smelting of lead and zinc sulfide ores is leached with sulfuric acid to solubilize the cadmium and thallium, which is present in concentrations ranging from several ppm to 2000 ppm in the dross. The solution is electrolyzed to produce a cadmium-thallium alloy containing 5 to 20 percent thallium. This alloy is then solubilized as the hydroxides by the addition of hot water, and the cadmium is then precipitated by the addition of sodium bicarbonate. The filtrate is then treated with hydrogen sulfide to precipitate thallous sulfide, which in turn is dissolved in sulfuric acid. Further electrolysis of the thallous sulfate solution yields pure thallium metal. The commercial sulfate is made by redissolving this metal in sulfuric acid and crystallizing from the saturated solution.[1287, 1433, 2239, 2242, 2240]

Use

Historically, thallium and thallium sulfate have been used as depilatories and in rodenticides and insecticides. However, their extreme toxicity has caused the U.S. Food and Drug Administration and the

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U.S. Department of Agriculture to ban their use for these purposes. Customers for thallium sulfate must furnish an affidavit stating that the material will not be used for rodenticide or insecticide manufacture.[1433, 2242]

These were the only uses for these materials, so that currently there is no commercial use to any significant extent. Parts per billion quantities of thallium have been used as dopants in NaI crystals for γ-ray scintillation counting and the U.S. Army is experimenting with Hg-Tl alloys for arctic thermometers, since the eutectic temperature of -59 C is 20 C lower than the freezing point of pure mercury.

In the first seven months of 1972, total thallium metal sales amounted to 10 lb, while thallium sulfate sales were 90 lb.[2242] Definite information is not available with regard to the ultimate disposition of these sold materials, but it has been reported that thallium is present in minor concentrations in various electrical connections, solders and fusible alloys.[1288] In 1964 it retailed for $7.50/lb.

2. TOXICOLOGY

Health and Safety Standards

The Threshold Limit Value (TLV) for thallium and thallium compounds is 0.1 mg/m^3.[0766] On contact with the skin, thallium and thallium compounds are readily solubilized by formation of the chloride, which then penetrates into the body. The toxicity and epidemiology of thallium and its compounds are not influenced by the mode of entry.[2238, 2241] If it is assumed that the average person breathes 10 m^3 air/day and drinks 2 liters water/day, the TLV may be translated into a maximum permissible water concentration of 0.5 ppm.

Epidemiology[2238, 2241, 2180]

The HEW 1971 Annual List of Toxic Substances[1312] reports LD50 of 29 mg/kg in the mouse and 15.8 mg/kg in the rat for Tl_2SO_4 administered orally. Since thallium rapidly solubilizes on contact with skin and clinical symptoms seem independent of mode of entry, it may be concluded that the pure element or other compounds would give approximately the same results.

The most dramatic clinical symptom is alopecia (baldness), and it is for this very property that is was widely used in patent medicine applications until its toxicity forced it off the market. It diffuses readily through the body and produces widespread damage to the nervous system and the gastrointestinal tract. Respiratory failure and cardiac depression have been noted in laboratory animals.

Diagnosis is complicated by the fact that it takes several days for symptoms to appear. The mechanisms are unknown, but as with most heavy metals, enzyme-poisoning is suspected. The metal is eventually excreted via the kidney, but removal is very slow, so that it may be classified as a "somewhat cumulative" poison. There is no known antidote; i.e., no way has been found either to precipitate and immobilize it within the body or to hasten its elimination through the kidney.

3. OTHER HAZARDS

Thallium and thallium compounds are relatively unreactive. On heating, fumes of the toxic, water-soluble Tl_2O are generated.

4. DEFINITION OF WASTE MANAGEMENT PRACTICES

Handling, Storage, and Transportation

The zinc dross containing the unconcentrated thallium at 2 to 2000 ppm is probably stockpiled on the producer's property with no special precautions.

The producer stores the refined thallium and thallium sulfate in Denver, Colorado in a prefab steel structure with asphalt paving and in a brick building with a concrete floor.[2242]

Thallium metal is marketed as sticks, 3/8-in.-diameter by 9 in., weighing approximately 6-1/2 oz, or as ingots, 2 in. by 3-9/16 in. by 7-9/16 in., weighing approximately 20 lb. These shapes are sealed in polyethylene plastic and packed in wooden boxes as required. Thallium sulfate is sold in 2-1/2-lb amber glass bottles and shipped in sawdust-filled mailing tubes packed in wooden boxes. Twenty-five-lb orders may be packed in polyethylene-lined steel pails, 9 in. by 7-1/2 in.[2242] U.S. Interstate Commerce Commission Regulations specify a maximum of 200 lb per shipment. Containers must be labeled "Poison B".[0278]

Disposal/Reuse

The zinc dross containing the trace quantities of thallium (2 to 2000 ppm) is not disposed of; rather it is stockpiled in anticipation of future use. Since thallium is not currently in production, no waste is being generated from the refining process. Previous experience indicates that airborne emissions from thallium production are nil, and the liquid effluent averages <0.1 ppm on delivery to the waste storage facility. The small amounts (<200 lb annually) of thallium and thallium compounds used commercially are widely dispersed in very small quantities. Wastes which incidentally contain small amounts of thallium are probably disposed of with no special precautions.

5. EVALUATION OF WASTE MANAGEMENT PRACTICES

Option No. 1 - Stockpiling of Zinc Dross Containing Trace Quantities of Thallium

This may be judged satisfactory. There is no evidence that thallium from this stockpile has become airborne or has leached into any ground water.

Option No. 2 - Production of Thallium from Stockpiled Zinc Dross

The procedures used in the past may be judged satisfactory, as can be seen from the following comparison:

	Tl Released[2242]	TLV[0766]
airborne emission	nil	0.1 mg/m^3
liquid effluent	<0.1 ppm	0.5 ppm

If and when production resumes, care must be taken to minimize worker exposure in the refining operation. The extractive metallurgy is relatively straightforward and well within the state-of-the-art, so worker protection should not present any untoward technical or economic problems.

6. CONCLUSIONS, RECOMMENDATIONS, AND SUITABILITY FOR NATIONAL DISPOSAL SITES

The handling, storage, and transportation of thallium and thallium sulfate are adequate at present and for the foreseeable future. If and when production resumes, worker exposure in the refining operation should be carefully monitored. Health and safety should not prove a problem.

Information on the disposal of incidental quantities of thallium after use is not available. While no incidences of thallium poisoning have been uncovered, it is nevertheless advisable for these disposals to be pinpointed in location and quantity. Additional education of users with regard to the hazards of thallium and thallium sulfate may prove desirable. Small quantities may easily be disposed of by sealing in polyethylene bags and burying in Class 1 landfills, i.e., landfills with no access to ground water.

Thallium and thallium sulfate can be handled quite adequately at the industrial level and are therefore not candidates for National Disposal Sites.

7. REFERENCES

0278. Code of Federal Regulations. Title--transportation, parts 71 to 90. (Revised as of January 1, 1967.) Washington, U.S. Government Printing Office, 1967. 794 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corp., 1968. 1,251 p.

1287. Mineral facts and problems. U.S. Bureau of Mines Bulletin 650. 1970. 1,291 p.

1288. Minerals yearbook. U.S. Bureau of Mines. 1969. 1,208 p.

1312. Christensen, H. E. Toxic substances: Annual list. U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, Rockville, Maryland. 1971. 512 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. New York, Interscience Publishers, 1966. 899 p.

2179. Personal communication. M. Coats, American Smelting and Refining Co. to M. Appel, TRW Systems, July 24, 1972. Thallium and thallium sulfate.

2180. International Occupational Safety and Health Information Centre. Four citations on thallium. CIS-34, CIS-40, CIS-41, CIS-67, no date.

2182. Personal communication. M. Appel, TRW Systems to M. Coats, American Smelting and Refining Co., 4742.3.72-096, July 24, 1972.

2238. Heyroth, F. F. Thallium: A review and summary of medical literature. U.S. Public Health Service Report Supplement 197. 1947.

2239. Prater, J. E., et al. Recovery of thallium from smelter products. U.S. Bureau of Mines Report RI-4900. 1952.

2240. Teats, R. Process for recovering thallium/Treating sulfate solutions of thallium and cadmium. U.S. Patent Numbers 2,060,453 and 2,011,882. Nov. 10, 1936 and Aug. 20, 1935.

2241. Pfizer Laboratories. Thallium poisoning. Pfizer Spectrum, 6(20):558, 1958.

2242. Personal communication. M. Coats, American Smelting and Refining Co. to M. Appel, TRW Systems, August 10, 1972.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name 430

IUC Name Thallium

Common Names Thallium

Structural Formula

Tl

Molecular Wt. 204 (1) Melting Pt. 303 C (1) Boiling Pt. 1457 C

Density (Condensed) 11.85 g/cc @ 20 C Density (gas) ______ @ ______ ______

Vapor Pressure (recommended 55 C and 20 C)

1 mm @ 825 C ______ @ ______ ______ @ ______

Flash Point ______ Autoignition Temp. ______

Flammability Limits in Air (wt %) Lower moderate (as dust) Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility

Cold Water insoluble Hot Water insoluble Ethanol insoluble

Others: HNO_3, H_2SO_4, slightly in HCl

Acid, Base Properties slightly basic

Highly Reactive with ______

Compatible with ______

Shipped in metal drums, wooden barrels either lined with paper or tongue-and-grooved

ICC Classification Thallium salts, solid: Poison B; poison label, 200 lb

Coast Guard Classification Thallium salts, solid: Poison B; poison label 200 lb

Comments

Code of Federal Regulations, Sec. 73.364 and 73.365

References (1) 1433

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name 431

IUC Name Thallous sulfate

Common Names Thallium sulfate

Structural Formula

Tl_2SO_4

Molecular Wt. 505(1) Melting Pt. 632 C(1) Boiling Pt. decomposes

Density (Condensed) 6.77 g/cc @ 20 C Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 4.87 g/100 ml Hot Water 15.57 g/100 ml Ethanol

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in metal drums, wooden barrels either lined with paper or tongue-and-grooved

ICC Classification Poison B; poison label, 200 lb Coast Guard Classification Poison B; poison label

Comments

Code of Federal Regulations, Sec. 73.364 and 73.365

References (1) 1433

PROFILE REPORT

Copper Acetylide (517) and Silver Acetylide (537)

1. GENERAL

The heavy metal salts of acetylene have the properties of primary explosives, but only cuprous acetylide has been found satisfactory for practical use. Cuprous acetylide is a russet or reddish-brown powder. It is prepared by the action of acetylene on an ammonia solution of cuprous chloride. In order to avoid contamination with cupric acetylide, a very sensitive explosive, cuprous acetylide is often precipitated in the presence of a reducing substance such as hydroxylamine, hydrazine sulfate, or sulfur dioxide. Cuprous acetylide forms as an impurity in hydrocarbon gas streams contaminated with acetylene when pipes or containers are contaminated with copper or copper-containing compounds. Cuprous acetylide explodes in air at 120 to 123 C, but in an acetylene atmosphere, under a pressure of 5 atm, it decomposes without explosion at 250 C. Cuprous acetylide is used as the chief component of match heads in electric fuses, being particularly susceptible to ignition by sparks or a glowing wire to give a sharp, hot flame.[2171] The physical/chemical properties of cuprous acetylide are summarized in the attached work sheet.

Silver acetylide, Ag_2C_2, is a white powder formed when acetylene is passed through an ammonical solution of silver chloride. It has even stronger explosive properties than cuprous acetylide due to its large negative heat of formation, $-\Delta H = 87.15$ Kcal/mole. It is of no practical use and has not been thoroughly characterized.[2171] It is not discussed further in this profile report.

2. TOXICOLOGY

Although the toxicity of cuprous acetylide has not been well established,[0766] it is considered to be less toxic than other copper compounds, due to its low solubility in body fluids.

3. OTHER HAZARDS

Cuprous acetylide is a primary, initiating explosive so sensitive to heat, sparks, impact and friction that it undergoes detonation when subjected to very mild thermal, electrical or mechanical shock by a spark, flame or percussion. Care must be taken that cuprous acetylide is not contaminated with cupric acetylide which may occur if cuprous chloride used in the preparation of the acetylide contains cupric salt. This is important since cupric acetylide is unstable and explodes on heating even between 50 and 70 C, and is even more sensitive to impact and friction than cuprous acetylide.[2171]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The sensitivity of cuprous acetylide to shock, friction, and heat as with most initiating agents, requires that all scrap and waste from preparation and purification be maintained wet for destruction. Cuprous acetylide is packaged wet for storage or shipment. Packaging is accomplished by placing not more than 25 lbs, wet with 20 percent water, in a duck-cloth or rubberized-cloth bag covered with a cap of the same material. The bag is then tied securely. Not more than six such bags are placed in the center of a watertight metal or wooden barrel, drum, or keg lined with a heavy close-fitting jute bag. The large bag containing cuprous acetylide is surrounded with well packed sawdust that has been saturated with water. The bag forming a liner is sewn closed before closing the barrel, drum, or keg. Not more than 150 lbs of initiating explosive is permitted in a single container. It is shipped wet under DOT regulations for an Explosive, Class "A".[2170]

Because cuprous acetylide is a sensitive primary explosive, it is recommended that no cuprous acetylide be released to the environment.

5. EVALUATION OF CURRENT AND NEAR FUTURE CUPROUS ACETYLIDE DISPOSAL PROCESSES

The only documented disposal process for cuprous acetylide is by detonation which is the disposal process generally employed for initiating explosives. Wet bags in the transporting container (described in Section 4) are transported to the disposal area. Then several bags are removed from the transporting container, carried to the destruction pit, placed in intimate contact with each other, and blasting caps are placed between the bags to initiate the cuprous acetylide. Remaining explosives must be kept behind a barricade with overhead protection during the destruction operations and located at a distance that assures safety. Personnel must be behind a similar barricade.[2170]

This disposal process is satisfactory on an interim basis, providing that copper salts liberated are not allowed to leach into ground water or near-by streams. Research is required to establish a fully satisfactory process for disposal of cuprous acetylide.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Cuprous acetylide is manufactured in limited quantities at plants making special electric fuses. Plants manufacturing such items have facilities for the disposal of cuprous acetylide discharged in waste streams, as scrap, or as excess material. Cuprous acetylide which is not processed for disposal at such manufacturers' facilities is a candidate for National Disposal Sites if the specific waste involved can be handled and transported safely. The disposal process to be employed at National Disposal Sites should be the open detonation procedure accepted as satisfactory on an interim basis in Section 5, until a fully satisfactory technique is developed. Surplus, scrap or obsolete materials containing copper acetylide should be handled only by qualified ordnance demolition personnel experienced in disposal of high sensitivity initiating explosives. The contaminated or scrap acetylide should be transported wet, in a vehicle properly equipped for safe transport of initiating explosives, and only to the nearest satisfactory disposal site. In the event that hazards to the disposal team and the public due to handling and transport to the nearest National Disposal Site are deemed excessive by the demolition team, the materials should be disposed of by detonation in a cleared area.

7. REFERENCES

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2171. Urbanski, Todeusz, Chemistry and technology of explosives, V.III, Warsawa, Polish Scientific Publishers, 1967. Translated by Jurecki, Marian, New York, Pergamon Press. 714 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name

IUC Name Cuprous acetylide

Common Names

Structural Formula

Cu_2C_2

Molecular Wt. 150.1(1) Melting Pt. 120 C explodes Boiling Pt.

Density (Condensed) @ Density (gas) @

Vapor Pressure (recommended 55°C and 20°C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water Insoluble Hot Water Insoluble Ethanol Insoluble

Others: Most organic solvents - insoluble, soluble in alkalies, KCN

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in Bags, wet

ICC Classification Explosive, Class A Coast Guard Classification Explosive, Class A

Comments

References (1) 0766

PROFILE REPORT
Cyanuric Triazide (519)

1. GENERAL

Cyanuric triazide is a powerful initiator in which azide groups are combined with a heterocyclic ring. First step in preparation is the reaction of chlorine and hydrogen cyanide to form cyanuric chloride, a trimer. Upon reaction of cyanuric chloride with sodium azide in an aqueous solution at room temperature cyanuric triazide is formed. Cyanuric triazide has initiating properties that are stronger than those of mercury fulminate. It is highly dangerous to handle and sensitive to impact and friction; it has been known to explode during manufacture. Large crystals, which explode even under the pressure of a rubber stopper are particularly dangerous. Its sensitivity accounts for the fact that the substance has found no practical application.[2171]

The physical/chemical properties for cyanuric triazide are summarized in the attached worksheet.

2. TOXICOLOGY

The toxicity of cyanuric triazide is unknown, but upon acidification toxic fumes are liberated.[0766] The liberated fumes probably contain hydrazoic acid which, in the concentration range of 0.7-7.0 mg/m^3, evokes marked symptoms of intoxication (see Profile Report on Hydrazoic Acid, [528]).

3. OTHER HAZARDS

Cyanuric triazide is a detonating agent that is so sensitive to heat, impact and friction that it undergoes detonation when subjected to a flame or percussion. Its ignition temperature, when heated at a rate of 20 C/min., is 205-208 C, but decomposition becomes evident on heating at a temperature slightly exceeding 100 C. It is exploded by an impact energy one-third of that which detonates mercury fulminate.[2171]

Because cyanuric triazide is so dangerous to handle and sensitive to impact and friction, it has found no practical application, and it is not manufactured or shipped.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Cyanuric triazide does not product NO_x as a decomposition product when detonated. For this reason, and because only small, experimental quantities are synthesized, cyanuric triazide laboratory wastes and scrap should be collected and detonated in a suitable remote destruction pit area.

5. EVALUATION OF CURRENT AND NEAR FUTURE CYANURIC TRIAZIDE DISPOSAL PROCESSES

Cyanuric triazide is at present not being manufactured and, therefore, specific disposal procedures are not published. If in the future it should become necessary to dispose of cyanuric triazide, the method recommended in the Ordnance Safety Manual for the disposal of initiating explosives could be used with care, if employed by an ordnance disposal team experienced in handling initiating explosives. When using the recommended procedure, bags containing the explosive,wet with water, are carried to a destruction pit, placed in intimate contact with each other, and a blasting cap placed between the bags to initiate the explosives. All remaining explosives should be kept behind a barricade with overhead protection during destruction operation. Personnel in the area should remain behind a similar barricade.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

There is no commercial production at present of cyanuric triazide, and provisions exist at most arsenals and explosive manufacturing plants which produce the material experimentally for its destruction. Any cyanuric triazide wastes not destroyed at such facilities are candidates for National Disposal Sites, if safe to handle and transport. The waste should be transported wet, in a vehicle properly equipped for safe transport of initiating explosives, and only to the nearest satisfactory disposal site. The process to be employed at the site should be detonation, as cited in Section 5. The wastes should be handled and transported only by a qualified ordnance team, experienced in handling sensitive initiators. If the wastes are unsafe to handle or transport to the National Disposal Site, they should be detonated at the nearest safe cleared area.

7. REFERENCES

0766. Sax, I. N., Dangerous properties of industrial materials. 3d. ed. New York, Reinhold Publishing Corporation. 1968. 1,251 p.

2170. Ordnance Corp., Department of the Army. Ordnance safety manual, ORDM7-224, Washington. 1951.

2171. Urbanski, Todeusz. Chemistry and technology of explosives v III, Warszawa, Polish Scientific Publishers, 1967. Translated by Jureki, Marian, New York, Pergamon Press. 714 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Cyanuric Triazide

IUC Name

Common Names

Structural Formula

$(CN)_3\ (N_3)_3$

Molecular Wt. 96 (1) Melting Pt. 100 C decomposes (1) Boiling Pt.

Density (Condensed) @ ° Density (gas) @ °

Vapor Pressure (recommended 55 C and 20 C)
slightly volatile
@ ° @ ° @ °

Flash Point ° Autoignition Temp. °

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water Insoluble (1) Hot Water Sparingly soluble (1) Ethanol soluble (1)

Others: Soluble-acetone, benzene, ether (1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in not shipped (1)

ICC Classification None (1) Coast Guard Classification none (1)

Comments

References (1) 2171

2

PROFILE REPORT

Primers and Detonators (520)

1. GENERAL

For purposes of this discussion, the following definitions will apply:

Primer: A primer is a small heat, impact and/or percussion-sensitive component which is charged with a single explosive mixture containing (for example) tetracene, PETN, mercury fulminate, lead azide or lead styphnate and other active or activating ingredients, which are used as first elements in explosive trains to ignite small arms propellants, black powder igniters and detonating agents. Primers will not initiate secondary high explosives reliably and do not destruct their containers when fired.

Detonator: Detonators are relatively small, sensitive explosive components which are employed to reliably initiate high order detonation in secondary high explosive charges; they can be initiated by the output of a primer or by percussion or electrical energy. Detonators are loaded with multiple charges including a primer charge and an intermediate/base charge. The primer charge materials are as mentioned above; intermediate/base charges consist of (for example) lead azide, tetryl, RDX, diazodinitrophenol (DDNP) or PETN. Detonators characteristically rupture their cases when fired.

Both the detonators and primers are generally housed in aluminum, copper, stainless or gilding metal cups. These are sealed with metal, paper or plastic at the open end.

The materials of interest from a hazardous waste standpoint are those which constitute the explosive mixture(s). As these are treated as individual compounds in other Profile Reports, the following statements will be limited to the characteristics of the materials as mixed and loaded or charged into primers and detonators.

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2. TOXICOLOGY

Primer and detonator explosive materials are relatively benign with respect to toxicology. Because the containers are sealed, the components can be considered non-toxic; ruptured or corroded containers, on the other hand, may expose the explosive materials. The toxicology of the materials may then be determined by reference to the appropriate Profile Reports.

3. OTHER HAZARDS

The explosive materials used in detonators and primers are extremely sensitive to friction, heat and impact, and undergo detonation when subjected to very mild energy input. As loaded or charged into components, the sensitivity is greatly reduced, but all handling should only be accomplished by experienced ordnance personnel. Operations involving primers and detonators should be governed by personnel safety regulations and supervised by a fully qualified safety engineer who is familiar with the characteristics of the components involved.

Older (possibly corroded) loaded components are a special case in that case-corrosion products in many instances tend to produce a marked increase in the sensitivity of certain explosive materials. In those instances in which the components are corroded, all handling should be remote-controlled and exposure of personnel minimized.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The sensitivity of the explosive mixtures used in primers and detonators generally requires that excess and scrap from charging operations be stored under water until destroyed by burning or chemical action. Primers and detonators are stored according to DOD regulations for Explosives, Group G, and shipped according to DOT regulations for Explosives, Class C.[2170]

5. EVALUATION OF CURRENT AND NEAR-FUTURE DISPOSAL PROCESSES

Option 1 - Detonator Destruction Furnace

The approved method referenced by the Ordnance Safety Manual for the destruction of detonators and primers is by burning or detonation in a specially designed detonator destruction furnace.[2170] In this furnace the components are fed to the combustion chamber by means of a channel chute and a special conveying device. Scrubbers are employed to remove toxic fumes and dusts such as NO_x, mercury, and lead.

Option 2 - Burning Pit Detonation

Detonators and primers are detonated in burning pits by applying heat from a fire or by electrical ignition. The components are placed on top of flammable substance such as straw and the flammable substance is ignited by means of a squib. Other explosives must be kept behind a barricade with overhead protection during destruction operations and located at a distance that assures safety. Personnel should be similarly shielded.[1147,2170] This destruction process is not entirely satisfactory because individual components may not detonate and will constitute a personnel hazard during cleanup. Some NO_x and toxic metal particles or compounds will also be liberated during the destruction process on an uncontrolled basis.

Option 3 - Chemical Action

Those primers and detonators which are charged with explosive materials which can be decomposed by acids may be chemically "killed" by immersion in an acid bath of sufficient strength as to destroy the seals. This method permits recovery of the metallic components as scrap, but is limited in application because the items must be segregated by explosive mixture prior to treatment.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Plants manufacturing primers and detonators have facilities for the disposal of the material discharged in waste streams, as scrap, or as excess material. Primers and detonators which are not processed for disposal at such manufacturers facilities are candidates for National Disposal Sites if the specific components can be handled and transported safely. The disposal process to be employed at National Disposal Sites should be Option 1, as recommended in Section 5. Surplus, scrap or obsolete materials should only be handled by qualified ordnance demolition personnel experienced in disposal of primers and detonators. In the event that hazards to the disposal team and the public due to the condition of the components or to handling and transport to the nearest National Disposal Site are deemed excessive by the demolition team, the items should be disposed of by detonation in a cleared area. Transportation of all primers and detonators should be in a vehicle properly equipped for safe transport of primary explosives, and only to the nearest satisfactory disposal site.

7. REFERENCES

1141. Department of the Army and the Air Force. Military explosives, TM9-1910, Washington. Apr. 1955. 336 p.

2169. Tedoroff, B. J., Encyclopedia of explosives and related items. v. 1. Picatinny Arsenal. 1960. 692 p.

2170. Ordnance Corp. Department of the Army. Ordnance safety manual, ORDM7-224. Washington. 1951.

PROFILE REPORT

Diazodinitrophenol (DDNP) (521)

GENERAL

Diazodinitrophenol (DDNP, Dinol, 2-diazo-1-oxy-4,6-dinitrobenzene) is a yellow or reddish-yellow amorphous powder. It is prepared by diazotizing picramic acid, $NH_2(NO_2)_2C_6H_2OH$, with sodium nitrite and hydrochloric acid. The dark-brown, granular product obtained is thoroughly washed with ice water and is purified by dissolving in hot acetone and precipitating by the addition of a large volume of ice water. Diazodinitrophenol is almost insoluble in water and alcohol, and is stored under water or an alcohol-water mixture.

Diazodinitrophenol is as sensitive to impact as mercury fulminate, and less sensitive to friction. Its sensitivity to friction is approximately that of lead azide, whereas it is more sensitive to heat than either mercury fulminate or lead azide. This makes for ease of ignition and thereby renders it slightly more adaptable for use than lead azide. It is considerably more stable than mercury fulminate, but not as stable as lead azide. Like lead azide, diazodinitrophenol has largely replaced mercury fulminate in commercial blasting caps and to some extent in ammunition.[0474,1147,1433,2171]

Chemical/physical properties are summarized in the attached worksheet.

2. TOXICOLOGY

Diazodinitrophenol is of unknown toxicity and a threshold limit has not been established.[0766] It is a compound containing nitrogroups and exposure should be limited. Compounds containing nitrogroups cause dilation of blood vessels, headaches, nausea, vomiting, methemoglobinemia, cyanosis, reduced blood pressure, central nervous system depression, and in large quantities coma and respiratory paralysis.[0766] Diazodinitrophenol

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has a low vapor pressure which indicates it probably would not enter the body through inhalation, but its solubility in organic solvents indicates it may enter the body through skin absorption.

3. OTHER HAZARDS

Diazodinitrophenol is a primary initiating explosive that is so sensitive to electrical discharge, heat, friction, and impact that it undergoes detonation when subjected to a very mild electrical, mechanical or thermal shock from a spark, flame or percussion. It has approximately the same sensitivity to friction as lead azide. The explosion temperature value is 180 C. It detonates when struck a sharp blow, but it burns with a flash, if ignited, when unconfined and even in quantities of several grams. However, even slight confinement causes the transition of burning into detonation.[1147] Water effectively desensitizes diazodinitrophenol; it is not detonated by a No. 8 blasting cap when wet with water.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

In addition to excess diazodinitrophenol, waste wash water and acetone-water used for the recrystallization of diazodinitrophenol will contain some diazodinitrophenol that will require treatment. After evaporation of acetone in the purification process, the residues must be kept wet until treated. Diazodinitrophenol collected from wash water sumps must also be kept wet until destroyed.

The sensitivity of diazodinitrophenol to shock and friction requires that it be packaged for storage or shipment in a wet condition. If shipment or storage under low temperature conditions is anticipated, a mixture of equal weights of water and ethanol is used. Packaging is accomplished by placing approximately 25 lb, wet with not less than 20 percent liquid in a duck-cloth or rubberized-cloth bag, covered with a cap of the same material. The bag is then tied securely. Not more than six such bags are placed in a larger bag of the same material. The larger bag is tied and placed in the center of a watertight metal or wooden barrel, drum, or keg lined with a heavy close-fitting jute bag. The large bag containing diazodinitrophenol is surrounded with well-packed sawdust that has been saturated with water or water-ethanol mixture. The bag forming a liner is sewn closed before closing the barrel, drum, or keg. Not more than 150 lb of diazodinitrophenol is permitted in a single container.[1147]

Diazodinitrophenol is shipped wet under DOT regulations for an "Explosive, Class A." It is covered by DOD regulations for an explosive with a sensitivity of Class 9, Group M.[0474,1147]

Because diazodinitrophenol is a sensitive high explosive, it is recommended that no diazodinitrophenol be released to the environment.

5. EVALUATION OF CURRENT AND NEAR FUTURE DIAZODINITROPHENOL DISPOSAL PROCESSES

The processing options for the disposal of diazodinitrophenol are briefly described in the following paragraphs together with recommendations as to adequacy. Detailed discussions of the processing operations are presented in the referenced diazodinitrophenol disposal reports. Because of the explosive hazard, it is recommended that the responsible disposal engineer become acquainted in detail with explosive disposal operations before attempting to dispose of diazodinitrophenol. Under no circumstances should waste diazodinitrophenol, or materials contaminated with DDNP be handled dry, or by anyone other than an experienced disposal team.

Option No. 1 - Detonation

When more than a few pounds of diazodinitrophenol are to be destroyed, detonation is the usual current disposal procedure. Wet diazodinitrophenol is transported to the disposal area. Then several bags are removed from the transporting container (described in Section 4.), carried to the destruction pit, placed in intimate contact with each other, and blasting caps are placed between the bags to initiate the diazodinitrophenol. Remaining explosives must be kept behind a barricade with overhead protection during the destruction operations and located at a distance that assures safety. Personnel must be behind a similar barricade.[1147,2168,2170,2230] This destruction process which liberates

NO_x is only satisfactory for small quantities of diazodinitrophenol. If large quantities are to be destroyed, the NO_x liberated can cause an environmental problem. Detonation is not recommended as a disposal procedure for DDNP unless safety considerations rule out transportation and handling for disposal via Option 3.

Option No. 2 - Treatment with Sodium Hydroxide

Small quantities of diazodinitrophenol such as residues left on parts can be decomposed to an unknown but non-explosive substance by adding the water-wet material to 100 times its weight of 10 percent sodium hydroxide. Nitrogen gas is evolved.[0474, 1147] The remaining residue, though not identified in the publications referenced, requires isolation and development of a method for destruction such as neutralization and solvent extraction, followed by incineration.

Option No. 3 - Controlled Incineration

The controlled slurry incineration technique currently being developed is recommended for disposal of waste DDNP. In the process, a 1 to 3 slurry of DDNP in water is fed to a rotary kiln incinerator equipped with suitable afterburner or alkaline scrubbing systems for the abatement of the NO_x liberated. If the alkaline scrubbing approach is employed for NO_x abatement, the scrubber liquid effluent (essentially a purge or shed-off from a recirculating system) is neutralized and diluted to where the combined nitrite and nitrate contents are below 250 ppm.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The manufacture and use of diazodinitrophenol is limited to those plants involved in the manufacture of commercial blasting caps and ammunition. Such plants have facilities for the disposal of diazodinitrophenol in waste streams, as scrap, or as excess material. DDNP waste and DDNP contaminated wastes which are not disposed of at such facilities are candidates for National Disposal Sites if the specific waste can be handled and transported safely. All DDNP wastes and DDNP contaminated wastes should be transported wet, in a vehicle properly equipped for the safe transport of high explosives, and only to the nearest satisfactory disposal area. The disposal process recommended for use with DDNP wastes at National Disposal Sites is the controlled incineration technique of Option 3, above. If DDNP contaminated wastes are to be disposed of and they are not capable of being handled as a slurry, the decontamination approach of Option 2 should be employed. DDNP wastes and DDNP contaminated wastes should only be handled by a qualified ordnance team, experienced in handling DDNP. If the disposal team considers the handling and transportation to a National Disposal Site of any DDNP waste would cause undue hazard to the team or the public, the waste should be destroyed by detonation in a cleared area.

7. REFERENCES

0474. Tomlinson, W. R., Jr. revised by O. E. Sheffield. Properties of explosives of military interest, Technical Report No. 1740, Rev. 1, Picatinny Arsenal, Apr. 1958. 348 p.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1,251 p.

2171. Urbanski, Todeusz, translated by Marian Jurecki, Chemistry and technology of explosives, v III, Warszawa, Polish Scientific Publishers, 1967, translation Pergamon Press, New York. 714 p.

2230. Department of the Air Force, Explosive safety manual, AF Manual AFM127-100, Washington. Dec. 2, 1971.

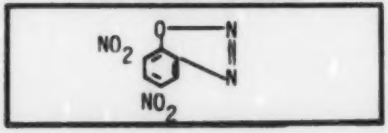
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Diazodinitrophenol

IUC Name 2-diazo-1-oxy-4,6-dinitrobenzene

Common Names

Structural Formula



Molecular Wt. 210(1) Melting Pt. 157 C Boiling Pt. 180 C explodes

Density (Condensed) 1.63g/cc @ 20 C Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.08g/100g at 25 C Hot Water Ethanol 0.84g/100g at 25

Others: 6.0g/100g acetone at 25 C

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in bags wet with water or ethanol-water

ICC Classification explosive, Class A Coast Guard Classification Explosive, Class A

Comments Primary explosive; very highly sensitive to impact, friction, heat, and electrical shock.

References (1) 0474

PROFILE REPORT

Dipentaerythritol-Hexanitrate (DPEHN) (522)

1. GENERAL

Dipentaerythritol-hexanitrate (DPEHN) is a white crystalline explosive used as an ingredient of priming compositions. It is present in pentaerythritol tetranitrate (PETN) as an impurity at a concentration of 2 to 3 percent. DPEHN is obtained in the pure state by fractional crystallization from moist acetone solution from which PETN has been precipitated. DPEHN can also be prepared by nitration of dipentaerythritol with nitric acid without the use of sulfuric acid.[0474]

The physical/chemical properties of DPEHN are summarized on the attached worksheet.

2. TOXICOLOGY

DPEHN has low contact toxicity since it is nearly insoluble in water. Because of its low solubility it cannot be absorbed through the skin. It is handled dry, not wet as is PETN, which makes inhalation of its dust possible. As with PETN, small quantities ingested will cause a decrease in blood pressure and larger doses could cause dyspnea and convulsions.[1147] The Threshold Limit Value (TLV) for DPEHN has not established, but should be similar to that of nitroglycerin (2 mg/cu.m).

3. OTHER HAZARDS

DPEHN is a detonating agent that is so sensitive to heat, impact, and friction that it undergoes detonation when subjected to very mild thermal, mechanical or electrical shock from a flame, an electric spark, or percussion. It explodes when heated to 255 C.[1147]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

DPEHN is stored dry in accordance with DOD regulations for a Class 9, Group M explosive and is classified by DOT as an Explosive, Class "A".[1147]

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DPEHN will be found as a waste along with PETN in wash water from PETN manufacture and in acetone-water solutions from which PETN is precipitated after its preparation. If DPEHN is manufactured by nitration of dipentaerythritol, the wash water and the acetone-water solution from which DPEHN is reprecipitated will contain DPEHN. Acetone from the acetone-water solution is recovered by evaporation and condensation. All DPEHN and PETN, if present, must be retained for destruction. Because it is a high explosive, no DPEHN should be released to the environment.

5. EVALUATION OF CURRENT AND NEAR FUTURE DPEHN DISPOSAL PROCESSES

The processing options for the disposal of DPEHN are briefly described in the following paragraphs, together with recommendations as to adequacy. Because of the explosive hazard, it is recommended that only personnel qualified in handling initiating agents perform the disposal operations.

Option 1 - Treatment with Ferrous Chloride

DPEHN as well as PETN is rapidly decomposed in a boiling solution of ferrous chloride.[1147] The products of this reaction are dipentaerythritol and ferric chloride, which are at present being diluted, neutralized, and discharged into streams. The method is satisfactory for use if the iron hydroxide and organic matter are removed via the secondary sludge sanitary waste treatment technique.

Option 2 - Detonation

Detonation is currently used as the disposal method when packaged DPEHN is to be destroyed. With this method several bags of DEPHN are carried to a remote destruction pit, placed in intimate contact with each other and blasting caps placed between the bags to initiate the DPEHN. Remaining explosives must be kept behind a barricade with overhead protection during the destruction operations. Personnel must be behind a similar barricade.[1174, 2170. 2230.] This process is not satisfactory for large quantities of DPEHN because NO_x will be liberated to the environment.

Option 3 - Controlled Incineration

Methods are currently being developed for the control combustion of water slurries of high explosives in rotary kiln incinerators equipped with flue gas scrubbers. DPEHN, in the form of a 1:3 slurry in water, may be destroyed by this technique, which is recommended for use in preference to Options 1 or 2 above.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The major use of DPEHN is in priming compositions in military and sporting ammunition. Ammunition manufacturing plants and ammunition storage depots have facilities for the disposal of waste DPEHN or wastes contaminated with DPEHN. DPEHN and DPEHN-contaminated wastes which are not processed for disposal at such facilities are candidates for National Disposal Sites if the specific waste can be handled and transported safely. DPEHN wastes should be transported wet, in watertight containers, in a vehicle properly equipped for safe transport of primary explosives and only to the nearest satisfactory disposal site. The containers must be thoroughly washed, and the wash water used for slurrying the waste DPEHN in preparation for disposal. The disposal process to be employed showed the controlled incineration recommended as Option 3 in Section 5. Surplus scrap or obsolete materials containing DPEHN should only be handled by qualified advance demolition personnel experienced in disposal of primary explosives. If hazards to the demolition team and the public are deemed excessive, the DPEHN should be destroyed by detonation in a cleared area.

7. REFERENCES

0474. Tomlinson, W. R., Jr., revised by O. E. Sheffield. Properties of explosives of military interest. Technical Report No. 1740, Rev. 1, Pictinny Arsenal, Apr. 1958. 348 p.

1147. Department of the Army and Air Force. Military explosives, TM9-1910. Washington. Apr. 1955. 336 p.

2170. Ordnance Corp., Department of the Army. Ordnance safety manual. ORDM7-224, Washington. 1951.

2230. Department of the Air Force. Explosive safety manual. AF Manual AFM127-100. Washington. Dec. 2, 1971.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Dipentaerythritol-Hexanitrate

IUC Name

Common Names DPEHN

Structural Formula

$C_{10}H_{16}N_6O_{19}$

Molecular Wt. 443(1)   Melting Pt. 73.7 C   Boiling Pt. 225 C explodes

Density (Condensed) 1.63 @ 23 ° C   Density (gas) @ °

Vapor Pressure (recommended 55 C and 20 C)

@ °   @ °   @ °

Flash Point °   Autoignition Temp. °

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water slightly soluble   Hot Water   Ethanol

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in bag dry in a waterproof container

ICC Classification Explosive, Class A   Coast Guard Classification Explosive, Class A

Comments

References (1) 0474

PROFILE REPORT

Gelatinized Nitrocellulose(PNC)(523)

1. GENERAL

Gelatinized nitrocellulose, which is often called plastisol nitrocellulose (PNC), is a white powder made up of spherical particles or aggregates of spherical particles. PNC does not have a definite chemical composition but varies from $C_{12}H_{17}(ONO_2)_3O_7$ to $C_{12}H_{14}(ONO_2)_6O_4$. Different impurities will be present which depend on the location of manufacture. PNC is used in the manufacture of solid propellant.[1142] The physical/chemical properties of PNC are summarized in the attached worksheet.

2. TOXICOLOGY

PNC is not generally considered toxic as such, or reactive with the skin. In a wet condition, however, the solvents used in its manufacture or for shipping may be dangerous and present the greatest toxicity hazard in its handling. For example, PNC made at the Naval Ordnance Station contains nitromethane because of its method of manufacture.[1142]

3. OTHER HAZARDS

Dry PNC is an extreme fire hazard, and proper care should be taken in its handling and storage. It should be handled or transported in conductive containers, which should be grounded at all times. Stainless steel is recommended for this service, since PNC may be affected by some metals. For storage and handling it should be treated the same as nitrocellulose, and, in general the explosive hazard should be considered similar to that of nitrocellulose.[1142] The precautions noted in the Profile Report on Nitrocellulose (534) should be adopted in handling PNC. Although PNC is not listed by DOT, the dry material should probably be classified as Explosive, Class A.

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PNC is less dangerous when stored wet with solvents or water. Due to the flammability of many of the solvents, a fire hazard still exists.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The sensitivity of PNC to fire and explosion, as with nitrocellulose, requires that all scrap and waste from preparation be maintained wet for destruction. Waste PNC should be collected in drums or fiberboard containers lined with conductive polyethylene bags.

Because PNC is an explosive and fire hazard, it is recommended that no PNC be released to the environment.

5. EVALUATION OF CURRENT AND NEAR FUTURE PNC DISPOSAL PROCESSES

Option 1 - Open Burning

The only process widely used for disposal of surplus, scrap or obsolete PNC is burning. The methods used for burning are generally in compliance with the procedures outlined in the military safety manuals.[2170,2230] PNC waste is placed in steel drums or fiberboard drums lined with conductive polyethylene bags. The PNC is covered with water, the drum closed and transported to a burning ground. The bags are removed, placed on straw or other flammable material, and the PNC and straw ignited with a black powder squib.[1142] As with all compounds containing nitro groups, considerable NO_x is released upon burning. This technique is therefore unsatisfactory.

Option 2 - Controlled Incineration

PNC wastes are readily amenable to controlled incineration. The two types of equipment in prototype use currently for this service are both afterburner and scrubber equipped, produce gaseous effluents stripped of NO_x and are equally acceptable from an environmental standpoint. The first disposal system is a municipal incinerator, fed by a conveyor, and possesses some minor safety drawbacks. The second type of equipment is a rotary kiln incinerator, which is fed with a slurry of explosive in water, in a 1 to 3 ratio. This method of disposal is preferred.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

PNC is manufactured and used at propellant manufacturing plants that have facilities for the disposal of surplus, scrap or obsolete PNC or propellant containing PNC. Disposal of PNC at these facilities by open burning is unsatisfactory. PNC wastes which are not destroyed by controlled incineration, as per Option 2 above, are candidates for National Disposal Sites. The disposal process recommended is that of Option 2. The wastes should be handled and transported only by a qualified ordnance disposal team. PNC wastes should be transported wet, in containers as noted in Section 4, to the nearest National Disposal Site.

7. REFERENCES

1142. JANAF Hazards Working Group. Chemical rocket propellant hazards. v.2. CPIA Publication.

2170. Ordnance Corp, Department of the Army. Ordnance safety manual, ORDM7-224, Washington. 1951.

2230. Department of the Air Force. Explosive safety manual, AF Manual AFM127-100. Washington. Dec. 2, 1971.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Gelatinized nitrocellulose

IUC Name

Common Names Plastisol Nitrocellulose(PNC)

Structural Formula

$C_{12}H_{17}(ONO_2)_3O_7$ to
$C_{12}H_{14}(ONO_2)_6)_4$

Molecular Wt. 459.28 to 594.29(1) Melting Pt. none Boiling Pt.

Density (Condensed) 1.55g/cc @ ° Density (gas) @ °

Vapor Pressure (recommended 55 C and 20 C)

@ ° @ ° @ °

Flash Point ° Autoignition Temp. 160 C(1)

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water Insoluble Hot Water Insoluble Ethanol Insoluble

Others:

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in Stainless steel drums

ICC Classification None Coast Guard Classification None

Comments

References (1) 1142

PROFILE REPORT

Glycol Dinitrate (525)

1. GENERAL

Glycol dinitrate, also known as ethylene glycol dinitrate, nitroglycol, and ethylene nitrate, is a colorless liquid that is used in conjunction with nitroglycerin in the manufacture of low-freezing dynamites. The sensitivity of glycol dinitrate precludes any use other than the manufacture of dynamite. It is manufactured by the use of mixed acids via the same process used to manufacture nitroglycerin (see Profile Report on Nitroglycerin [307]). The nitration can be carried out at a lower temperature because the starting material, glycol, is less viscous than glycerol, the starting material for nitroglycerin.[0474, 1142, 1433]

Glycol dinitrate is manufactured by nitrating of glycol in a "mixed acid" containing about 40 percent nitric acid, 59.5 percent sulfuric acid and 0.5 percent water. After nitration of the glycol is complete, the resulting emulsion is allowed to stand in a separating tank until a supernatant layer forms which contains glycol dinitrate contaminated with nitric and sulfuric acids. This supernatant layer is separated, washed first with water, then with sodium carbonate solution and then further with water until the glycol dinitrate is neutral. Special filters are used to collect the glycol dinitrate from the waste and wash water systems.

The physical/chemical properties for glycol dinitrate are summarized in the attached work sheet.

2. TOXICOLOGY

Because of the greater volatility of glycol dinitrate, inhalation of its vapors is more of a problem than with nitroglycerin. Glycol dinitrate can cause dilation of blood vessels, headaches, nausea, vomiting, methemoglobinemia, cyanosis, reduced blood pressure, central nervous system depression, coma and respiratory paralysis through inhalation, ingestion or skin absorption.[0433] The Threshold Limit Value (TLV) for glycol dinitrate is 0.2 ppm.[0225]

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3. OTHER HAZARDS

Glycol dinitrate is a powerful explosive whose decomposition into gaseous products is accompanied by the evolution of large quantities of heat and a shock wave. Glycol dinitrate is very sensitive to mechanical shock or impact, undergoing detonation under a falling weight of 1 lb at a height of 4 cm.[0474] Wastes containing glycol dinitrate should be handled only by an experienced explosives and ordnance disposal team.

4. DEFINITION OF ADEQUATE WASTE TREATMENT

Handling, Storage, Transportation and Personnel Safety in Handling

Procedures for safe handling, transportation and storage of glycol dinitrate are nearly identical to those for nitroglycerin and have been described by the JANAF Hazards Working Group.[1142] Recommended procedures for manufacturing plant layout and materials of construction, personnel requirements, manufacturing flow description, process control and disposition of waste are also included.

Glycol dinitrate, because of hazards in handling, is never transported as such beyond the plant in which it is manufactured.[1433]

Disposal of Waste Glycol Dinitrate from the Manufacturing Process

Wash waters and mixed acid nitrating solutions from the manufacturing process for glycol dinitrate are stored until all dissolved/entrained glycol dinitrate has decomposed.[1142] The spent acid is normally recovered by elevated temperature processing techniques.

5. EVALUATION OF CURRENT AND NEAR FUTURE GLYCOL DINITRATE DISPOSAL PROCESSES

Glycol dinitrate collected from spills and catch tanks, or considered unsuitable for use (contaminated or unstable to the KI test), is disposed of by careful burning after absorption in sawdust, wood pulp or fullers earth. If glycol dinitrate is spilled on the ground, the contaminated ground is removed with low impact tools and is burned. Ignition of glycol dinitrate waste is usually accomplished by a black powder squib on the surface. All burning is performed in a remote area. Although the products of combustion contain considerable NO_x, pollution-free methods for glycol dinitrate disposal are not in wide use.[1142]

Alkali sulfides are useful as glycol dinitrate decontamination agents. Sodium sulfide, water, acetone, and methanol as a mixture is used for this purpose. A 17.5 percent sodium sulfide solution in water is sometimes used, with or without organic solvents. The glycol dinitrate is saponified and reduced by this material to insensitive compounds. This method is used with minute quantities of glycol dinitrate since the decomposition reactions are exothermic; with larger quantities, where the heat of reaction is not dissipated, there is danger of explosion due to thermal shock. The alkali sulfide method of decomposition is usually limited to cleaning equipment. This technique liberates sulfur compounds with a very disagreeable, pungent odor, along with vapor of the organic solvents used.[1142] This method is not recommended except on a very small scale.

Investigations are being conducted to develop better methods for the disposal of nitroglycerin than the open-burning techniques currently used. These methods when developed can probably be used for the disposal of glycol dinitrate. Methods showing promise are bacterial attack and controlled (scrubber-equipped) incineration, but neither of these methods are available for wide use at this time. Additional research is required.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Glycol dinitrate is not normally a candidate for National Disposal Sites because it is not transported as such and facilities for its disposal are available at the sites where it is manufactured. It is anticipated that a system to effect minimum impact disposal of small quantities of glycol dinitrate blended with nitroglycerin in the form of dynamite will be required at National Disposal Sites. Controlled incineration of safe lot sizes in a scrubber-equipped incinerator is the recommended process for disposal.

7. REFERENCES

0225. American Conference of Government Industrial Hygienists. Threshold limit values for 1971. Occupational Hazards, p 35-40. Aug. 1971.

0474. Tomlinson, W.R., Jr., revised by O. E. Sheffield. Properties of explosives of military interest, Technical Report No. 1740, Rev. 1, Picatinny Arsenal, Apr. 1958. 348 p.

1142. JANAF Hazard Working Group. Chemical rocket propellant hazards: solid rocket propellant handling, processing, storage and transportation. v.2 pt.1-3. CPIA Publication No. 194, Silver Springs, Maryland. 99 p.

1433. Kirk-Othmer, Encyclopedia of chemical technology. 2 ed. 22v. New York, Interscience Publishers. 1963-1971.

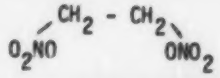
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Glycol Dinitrate

IUC Name

Common Names Ethylene Glycol Dinitrate, Nitroglycol, Ethylene Nitrate

Structural Formula



$O_2NO-CH_2-CH_2-ONO_2$

Molecular Wt. 152$^{(1)}$ Melting Pt. -22.8 C$^{(1)}$ Boiling Pt. 257 explodes$^{(1}$

Density (Condensed) 1.489 @ 20 C Density (gas) @ °

Vapor Pressure (recommended 55 C and 20 C)

0.05 torr @ 20 C$^{(1)}$ 1.4 torr @ 60 C$^{(1)}$ 5.9 torr @ 80 C$^{(1}$

Flash Point ° Autoignition Temp. °

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.68g/100g at 20 C$^{(1)}$ Hot Water 0.92g/100g at 50 C$^{(1)}$ Ethanol

Others:

Acid, Base Properties

Highly Reactive with Reducing substances$^{(1)}$

Compatible with

Shipped in

ICC Classification not shipped$^{(1)}$ Coast Guard Classification not shipped$^{(1)}$

Comments

References (1) 0474

PROFILE REPORT

Lead Azide (529)

1. GENERAL

Lead azide is an important primary explosive. It exists in two allotropic forms: the alpha-form is orthorthombic, the beta-form is monoclinic. The crystallographically stable modification is the alpha-form. It is prepared by rapidly stirring a solution of lead acetate or lead nitrate and adding sodium azide. The beta-form is prepared by slow diffusion of sodium azide and lead nitrate solutions. This form has a tendency to revert to the alpha-form, either on standing at elevated temperature (ca 160 C), or when crystals of the beta-form are kept in water containing crystals of the alpha-form.

Lead azide, like hydrazoic acid, (Profile Report, Hydrazoic Acid, [528]) is liable to undergo oxidation and reduction reactions. It is partially decomposed by atmospheric oxygen to form free hydrazoic acid, nitrogen, and ammonia. The reaction is promoted by carbon dioxide in the air. When boiled in water, lead azide undergoes slow decomposition with the evolution of hydrazoic acid. Lead azide is completely decomposed by the action of dilute nitric or acetic acid in which sodium nitrate has been dissolved, and the products are soluble.

Lead azide detonates easily, with a high rate of propagation which is 4,500 m/sec at a density of 3.8 and 5,300 m/sec at a density of 4.6. The disadvantage of lead azide is the difficulty in igniting it with a flame. For this reason, when used as a primary explosive, it is usually mixed with lead styphnate, a substance particularly easy to ignite, or a charge of lead azide in a detonator is covered with a layer of lead styphnate. Lead azide passes very rapidly from burning to detonation. When used in very small amounts, it is therefore capable of initiating detonation in other explosives. It is suitable for use in detonators though it cannot be used in caps.[474,1147,2169,2171]

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For military use in the United States only one grade of lead azide is manufactured, dextrinated lead azide. The dextrinated material (91.5% lead azide, min.) is manufactured by precipitating lead azide from a solution containing dextrin. The dextrin acts as a binding agent for the particles precipitated. All of the mother liquid and wash waters are collected in a vat and treated as described in Section 5.[9474,2171]

The physical/chemical properties of lead azide are summarized in the attached work sheet.

2. TOXICOLOGY

Lead azide because of its low solubility, has moderate contact toxicity, but is highly toxic when ingested or inhaled, due to the ease with which it hydrolyzes. A Threshold Limit Value (TLV) for an 8-hr working day of 40-hr week has not been established by the American Conference of Government Industrial Hygienists, but a recommended maximum level for lead azide in air to be breathed is 0.2 mg/m^3.[1147] This value seems to be consistent with the TLV value for lead of 0.2 mg/m^3.[0225] Lead azide, when entering the human system through inhalation or ingestion, can produce both lead and azide intoxication (see Profile Reports on Hydrazoic Acid [528], and Lead, [233]).[0766]

3. OTHER HAZARDS

Lead azide is a primary explosive and detonating agent that is so sensitive to electrical discharge heat, impact, and friction that it undergoes detonation when subjected to very mild thermal, mechanical or electrical shock by flame percussion or electrical discharge. Old or contaminated lead azide presents an extreme hazard and must be handled with the greatest of care. Dextrinated lead azide, the standard military form, is less sensitive to impact than mercury fulminate, lead styphnate, diazodinitrophenol, tetrazene, or pure crystalline lead azide.

Because of the extreme sensitivity, and the high degree of explosive hazard, wastes containing lead azide should be handled only by an experienced explosives and ordnance disposal team. Normal procedures are to handle lead azide as a slurry in water, to minimize hazard.

Spontaneous explosions of lead azide take place during crystallization. Before attempting crystallization of lead azide, the details in the various references given throughout the report should be consulted. Applying pressure, friction, heat, flame, or electric discharge to crystals must be avoided to prevent explosions. Long contact with copper or copper-containing alloys must be avoided because a reaction takes place that produces copper azide, a substance more sensitive to explosion than lead azide. As with hydrazoic acid, lead azide is decomposed by ultraviolet light.[0474]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Dry lead azide does not react with or corrode, steel, iron, nickel, aluminum, lead, zinc, copper, tin, or cadmium. It does not affect coatings of acidproof paint. Lead azide in the presence of moisture corrodes zinc and copper. With copper, it forms the extremely sensitive and dangerous copper azide. For this reason lead azide is not loaded in direct contact with uncoated copper or its alloys; aluminum is generally used for detonator shells.[0474,1147]

Lead azide (dextrinated only) is shipped wet with water under DOT regulations for Explosive, Class A. It is covered by Army regulations for an explosive with a sensitivity for Class 9, Group M.[0474,0766] A serious explosion hazard exists when dust particles settle out over a long time. Lead azides low solubility in water (0.02g/100g) reduces the possibility of discharging it in an aqueous solution. Suspended lead azide must be filtered out to avoid an explosion hazard. After destruction of lead azide by nitrous acid the effluents must contain less than 45 ppm of nitrate or nitrite.[0536]

Recommended maximum concentrations of lead azide in effluent streams released to the environment are as follows:

Contaminant and Environment	Maximum Concentration at Source Point	Basis of Recommendation
Lead azide released to the atmosphere as particulate inside the boundaries of the processing plant.	0.2 mg/M^3/24 hrs.	Recommended maximum.[0474]
Lead azide released to the air as particulate outside the boundaries of the processing plant.	None	An explosive material should not be permitted to collect outside the plant.
Lead azide released in water to material streams or sewers.	0.1 mg per liter	Level above which aquatic life is endangered.[0563]

5. EVALUATION OF CURRENT AND NEAR FUTURE LEAD AZIDE DISPOSAL PROCESSES

The processing options for the disposal of lead azide are briefly described in the following paragraphs together with recommendations as to adequacy. Detailed discussions of the processing operations are presented in the referenced lead azide disposal reports. Because of the explosive hazard, it is recommended that companies or engineers starting lead azide disposal operations visit an existing disposal unit operation to acquaint the responsible engineer with the operation prior to start-up of the proposed disposal processes.

Option No. 1 - Detonation

Detonation is the method currently employed when large to medium quantities of initiating explosives such as lead azide are to be destroyed. Bags containing small quantities of lead azide are kept wet while being transported to the demolition area. Several bags are removed from a container, carried to the destruction pit, and placed in intimate contact with each other. Blasting caps are placed between the bags to initiate the lead azide. The blasting caps are initiated by electrical current, with the operator at a safe distance, behind a barricade with overhead protection. Remaining explosives are kept behind a barricade with overhead protection during the destruction operations and located at a distance that assures safety.[1147,2168,2170] The destruction pit by necessity must be in a remote location that should assure limited hazard to the public from contamination of the atmosphere by lead. The destruction pit must be in alkaline soil or soil treated with lime to avoid leaching of lead into drainage water. This technique is viewed as unsatisfactory, unless hazards to demolition team personnel and the public, due to transportation and handling for disposal via Option No. 4 and Option No. 6, outweigh the ecological impact of load released to the atmosphere by the detonation technique.

Option 2 - Treatment with Sodium Hydroxide

Lead azide may be destroyed chemically by mixing it with at least five times its weight of a 10 percent sodium hydroxide solution. The mixture is allowed to stand 16 hours and the supernatant solution containing sodium azide is decanted. The sodium azide solution is disposed of by draining into the ground.[0474,1147] The lead is precipitated and can be recovered (see Profile Report on Lead [233]). This method is extensively used for waste streams from lead azide manufacture. This procedure is not recommended unless the effluent is diluted to a sodium azide content less than 1 mg/ℓ.

Option No. 3 - Bichromate Treatment

Lead azide may be converted to potassium azide by reacting the explosive with a 10 percent solution of potassium bichromate until more lead chromate is precipitated.[0474,1147] This method is not satisfactory for other than laboratory use with very small (milligram) quantities of lead ozide.

Option No. 4 - Treatment with Nitrite

Lead azide wetted with 500 times its weight of water may be destroyed by adding to the lead azide 12 times its weight of 25 percent sodium nitrite, stirring, and then adding 14 times its weight of 36 percent nitric acid or glacial acetic acid. Aliquots of this solution are tested for complete azide destruction by testing with a ferric chloride solution; a red color indicates the presence of azide.[0474,1147] After complete destruction of the azide, the pH is adjusted to 6.0 to 9.0 and the solution should be diluted to a nitrite and nitrate concentration of less than 45 ppm, a typical maximum allowable concentration in an effluent being discharged to a storm sewer, lake, or stream.[0536] Lead will be precipitated when the reaction solution is neutralized with lime or other basic material. This is a satisfactory method that permits recovery of the lead, if the NO_x vapors liberated are destroyed by controlled incineration, or removed by scrubbing.

Option No. 5 - Treatment with Ceric Ammonium Nitrate

Lead azide may be decomposed by reaction with 50 times its weight of 15 percent ceric ammonium nitrate. The azide is oxidized to form nitrogen [1147] and the lead is subsequently precipitated as lead sulfate. This method though satisfactory, requires the use of a more expensive chemical than is used in the other processes described.

Option No. 6 - Electrolytic Destruction

Because about 300,000 lb of special purpose lead azide are stored in the United States, the Burlington AEC plant has developed in the laboratory a new electrolytic process. This process converts the lead azide to metallic lead and nitrogen. The lead azide is placed into solution by treatment with sodium hydroxide in an electrolytic cell with a lead cathode and a stainless steel anode. This method is recommended as most satisfactory of the options reviews.

The reactions at the cathode and anode are as follows:

Cathode

$$Pb^{++} + 2e^- \rightarrow Pb^\circ$$

$$4H_2O + 4e^- \rightarrow 2H_2 + 4OH^-$$

Anode

$$2N_3^- \rightarrow 3N_2 + 2e^-$$

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$$

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The major use of lead azide is as an initiating agent in military and sporting ammunition, and in detonators. Ammunition manufacturing plants and ammunition storage depots have facilities for disposal of lead azide discharged in waste streams, as scrap or as excess material. Lead azide, and lead azide contaminated wastes which are not processed for disposal at such facilities are candidates for disposal at National Disposal Sites if the specific waste can be handled and transportte for disposal at such facilities are candidates for disposal at National Disposal Sites if the specific waste can be handled and transported safely. The contaminated waste or scrap azide should be transported wet, in a vehicle properly equipped for the safe transport and primary explosives, and only to the nearest satisfactory disposal site. The disposal process to be employed, if the material is safe for use of the technique, should be Option No. 6 - electrolytic destruction. Surplus, scrap, or obsolete lead azide and lead azide, contaminated materials should only be handled by qualified ordnance demolition personnel experienced in disposal of lead azide. In the event that hazards to the disposal team and the public, due to handling and transport to the nearest disposal site, are deemed excessive or if the material is suspected in any way of contamination with copper azide, the waste should be disposed of by detonation in a cleared area.

7. REFERENCES

0225. American Conference of Government Industrial Hygienists. Threshold for 1971. Occupational Hazards, Aug. 1971. p. 35-40.

0474. Tomlinson, W.R., Jr., revised by O.E. Sheffield. Properties of explosives of military interest, Technical Report No. 1740, Rev. 1, Picatinny Arsenal, Apr. 1958. 348 p.

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0766. Sax, N.I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 1, 251 p.

1147. Department of the Army and the Air Force. Military explosives. TM9-1910, Washington, Apr. 1955. 336 p.

1699. Engel, R.E., D.I. Hammer, J.M. Horton, N. Lane, and L.A. Plummlee. Environmental lead and public health. Report prepared by Environmental Protection Agency, Air Pollution Control Office, Publication No. AP-90. Research Triangle Park, 1971. 34 p.

2168. Department of Defense. Ammunition explosives dangerous material safety manual for use in procurement and administration of controls, Washington, Mar. 1967. (Draft only).

2169. Fedoroff, B.T. Encyclopedia of explosives and related items. v. 1. Dover, Picatinny Arsenal, 1960. 692 p.

2170. Ordnance Corp, Department of the Army. Ordnance safety manual, ORDM7-224, Washington, 1951. p.

2171. Urbanski, Todeusz. Chemistry and technology of explosives VIII, Warszawa, Polish Scientific Publishers, 1967. Translated by Jurecki, Marian, New York, Pergamon Press. 714 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead Azide

IUC Name Lead Azide

Common Names

Structural Formula

$Pb(N_3)_2$

Molecular Wt. 291(1) Melting Pt. 320 C explode(1) Boiling Pt.

Density (Condensed) 4.38 g/ml(1) @ *25 C(1) Density (gas) @ °

Vapor Pressure (recommended 55 C and 20 C)

@ ° @ ° @ °

Flash Point ° Autoignition Temp. °

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.02g/100g at 18 C(1) Hot Water 0.09g/100g at 70 C(1) Ethanol insoluble(1)

Others: Ether - insoluble(1)

Acid, Base Properties

Highly Reactive with sodium hydroxide(1)

Compatible with steel, nickel, aluminum, lead (1)

Shipped in

ICC Classification Explosive A(1) Coast Guard Classification Explosive A(1)

Comments *Dextrinated form

References (1) 1416

PROFILE REPORT

Lead Styphnate (Lead Trinitroresorcinate) (531)

1. GENERAL

Lead styphnate or lead 2,4,6-trinitroresorcinate is used as an initiating agent in military ammunition. It is slightly less sensitive to impact than mercury fulminate or diazodinitrophenol, but is more sensitive than lead azide. It has an explosion temperature test value of 282 C which is less than that for lead azide (345 C) but much greater than those for mercury fulminate (210 C) and diazodinitrophenol (180 C). It is much more easily ignited by an electrical spark than is mercury fulminate, lead azide, or diazodinitrophenol. In spite of the fact that lead styphnate has a high rate of detonation, it is a relatively poor initiator of detonation. However, the ease of ignition of lead styphnate renders it suitable for use as an igniting charge for lead azide and as an ingredient of priming compositions. It is used extensively in the United States as an igniting charge for lead azide.[1147, 1433, 2171]

The physical/chemical properties of lead styphnate are summarized in the attached work sheet.

2. TOXICOLOGY

Lead styphnate does not have a sufficient vapor pressure to permit an appreciable concentration in air except as a dust. The toxic effects produced combine those of lead and the nitrocompounds. Organic lead compounds may be absorbed through the skin as well as through the lungs and are selectively absorbed by the central nervous system. Because of this, and the toxicity of lead (discussed in the Profile Report on Lead [233]), skin contact and areas laden with lead styphnate dust should be avoided. The amount of a lead compound in the work area should not exceed 0.2 mg of a lead compound per cubic meter for an 8-hr working day of a 40-hr week (TLV).[0225]

3. OTHER HAZARDS

Lead styphnate is a detonating agent that is so sensitive to heat, impact, electrical discharge, and friction that it undergoes detonation when subjected to very mild thermal, electrical or mechanical shock by a flame, an electrical spark, or percussion. Because of the low solubility of lead styphnate, water may be used as a wetting agent to protect the lead styphnate from accidental explosion.[0766]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The sensitivity of lead styphnate to shock and friction requires that it be packaged wet, with water as the wetting agent. If it is stored or shipped under low temperature conditions, a wetting agent consisting of equal weights of ethanol and water is used. Approximately 25 lb of lead styphnate wetted with not less than 20 percent of liquid is placed for storage or shipment in a duck-cloth-or rubberized-cloth bag and covered with a cap of the same material. The bag is tied and placed in a metal or wooden barrel, drum or keg containing sawdust saturated with water or ethanol-water mixture. Not more than 150 lb of lead styphnate is permitted in a single container. Lead styphnate is classified by DOT as an Explosive, Class "A" and classified by the army as a Class 9, Group M (wet) explosive.[1147]

Lead styphnate is not recovered when contaminated but is destroyed. Because of its sensitivity, waste streams containing lead styphnate should not be permitted. The maximum quantity of lead styphnate or lead in any form to be released to the environment are as follows:

Containment and Environment	Maximum Concentration and Point Source Release Rate	Basis of Recommendation
Lead styphnate released to the atmosphere as a dust	$0.002\ mg/M^3/24$ hrs	0.01 TLV for lead compounds.
Lead in any form in water to natural streams	0.1 mg per liter	Level above which decomposition of organic matter is inhibited. 1694

5. EVALUATION OF CURRENT AND NEAR FUTURE LEAD STYPHNATE DISPOSAL PROCESSES

The processing options for the disposal of lead styphnate are briefly described in the following paragraphs together with recommendations as to adequacy. Detailed discussions of the processing options are presented in the referenced lead styphnate disposal reports. It is recommended, because of the explosive hazard, a disposal unit operation be visited to acquaint the responsible engineer with the operation before disposal operations are attempted.

Option No. 1 - Detonation

When large to medium quantities of initiating explosives such as lead styphnate are to be destroyed, detonation is the method most often used. Bags containing small quantities of lead styphnate must be kept wet while being transported to the demolition area. Several bags are removed from a container, carried to the destruction pit, placed in intimate contact with each other, and blasting caps are placed between the bags to initiate the lead styphnate. Remaining lead styphnate must be kept behind a barricade with overhead protection during the destruction operation and located at a distance that assures safety.[1147,2168,2170] The destruction pit by necessity must be in a remote location that should assure limited hazard to the public due to contamination of the environment by lead. The destruction pit must be in alkaline soil or soil treated with lime to avoid leaching of lead into drainage water. This technique is not regarded as satisfactory unless hazards to the disposal team and the public from satisfactory disposal via Option 3 or Option 5 out weigh the ecological impact.

Option No. 2 - Treatment with Sodium Dichromate

Small quantities of lead styphnate left on manufacturing equipment or in filter or wash solution are usually decomposed chemically. Lead styphnate is decomposed by first reacting it with at least 40 times its weight of a 20 percent sodium hydroxide solution or 100 times its weight of a 20 percent ammonium acetate solution. Then a 10 percent solution of sodium dichromate is added until the weight of sodium dichromate equals that weight of lead styphnate.[0474, 1147] The lead is thereby converted to insoluble basic lead chromate which is separated and disposed of in a landfill. The trinitroresorcinol formed is washed into the industrial waste drain along with any excess sodium dichromate. This process is not recommended.

Option No. 3 - Reaction with Na_2CO_3

Techniques under investigation include disposal of waste lead styphnate by reacting the material with sodium carbonate solution to yield insoluble basic lead carbonate, and an alkaline solution of trinitroresorcinol (TNR). The basic lead carbonate is separated, washed and recycled, and the trinitroresorcinol recovered for re-use in the manufacture of lead styphnate. The process is in the early development stage, and will be satisfactory if the TNR is recovered so that outfall effluents contain less than 0.5 ppm.

Option No. 4 - Reduction with NaOH and Aluminum

A current desensitization process is to react the lead styphnate with sodium hydroxide, sodium carbonate and aluminum, using live steam as a heat source. The reaction products are non-explosive and include sodium aluminate, insoluble (basic) lead carbonate, and the disodium salt of aminoresorcinol. With the exception of the lead carbonate, which is separated, the materials are discharged as a solution to the industrial waste system. The technique produces effective desensitization of the styphnate, but requires secondary treatment to destroy the aminoresorcinol, and to precipitate the aluminum.

Option No. 5 - Controlled Combustion

The most promising technique under development for disposal of lead styphnate and other high explosives is the controlled combustion process, which employs a rotary kiln incinerator equipped with appropriate scrubbing devices. The styphnate is then fed to the incinerator as a slurry in water, at a weight ratio, styphnate to water, of 1:3. The scrubber effluent would then require treatment for recovery of the particulate lead oxide formed as a combustion product. This process is recommended for disposal of lead styphnate.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The major use of lead styphnate is as an initiating agent in military ammunition. Military ammunition manufacturing plants and ammunition storage depots have facilities for disposal of lead styphnate discharged in waste streams as scrap, or as a contaminant of other wastes. Styphnate wastes which is not processed for disposal at such facilities are candidates for National Disposal Sites if the specific waste can be handled and transported safely. The styphnate waste should be transported wet in a vehicle specially equipped for the safe transport of primary explosives, and only to the nearest disposal site. The disposal process to be employed at National Disposal Sites should be that cited as Option 5 in Section 5. Styphnate wastes, and wastes contaminated with lead styphnate should be handled only a qualified ordnance demolition team experienced in handling lead styphnate. If hazards to the team and the public from transportation and handling are deemed excessive by the demolition team, the waste should be disposed of by detonation in a cleared area.

7. REFERENCES

0225. American Conference of Government Industrial Hygienists. Threshold limits for 1971. Occupational Hazards, Aug. 1971. p. 35-40.

0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 251 p.

1147. Department of the Army and the Air Force. Military explosives, TM9-1910. Washington, Apr. 1955. 336 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. 22 v. New York, Interscience Publishers, 1963.

1699. Engel, R. E., D. I. Hammer, J. R. M. Horton, N. M. Lane, and L. A. Plumlee. Environmental lead and public health. Report prepared by Environmental Protection Agency, Air Pollution Control Office, Publication No. AP-90, Research Triangle Park, 1971. 34 p.

2168. Department of Defense. Ammunition explosives dangerous materials safety manual for use in procurement and administration of controls. Washington. Mar. 1967. (Draft only)

2170. Ordnance Corps, Department of the Army. Ordnance safety manual, ORDM7-224. Washington, 1951.

2171. Urbanski, Todeusz. Chemistry and technology of explosives, v III, Warszawa, Polish Scientific Publishers, 1967. Translated by Jurecki, Marian, New York, Pergamon Press. 714 p.

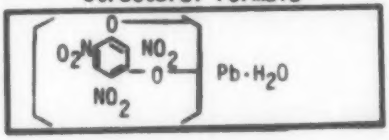
HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Lead styphnate

IUC Name Lead styphnate

Common Names

Structural Formula



Molecular Wt. 468(1) Melting Pt. 260-310 C explodes Boiling Pt.

Density (Condensed) 3.02g/cc @ 20 C Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble Hot Water Ethanol

Others: glycol diacetate 0.1g/100g at 20 C

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in bag under water

ICC Classification Explosive, Class A Coast Guard Classification Explosive, Class A

Comments

References (1) 0474

PROFILE REPORT

Mannitol Hexanitrate (532)

1. GENERAL

D-mannitol hexanitrate, "nitromannitol," or "nitromannite" is a strong explosive with a positive oxygen balance. Its decomposition goes according to the equation:

$$C_6H_8(ONO_2)_6 \rightarrow 6CO_2 + 4H_2O + 3N_2 + O_2 + 1512 \text{ Kcal/Kg}$$

It is initiated by shock as readily as nitroglycerine. In direct contact with a flame it melts and is ignited in the open air with difficulty. Once kindled mannitol hexanitrate burns rapidly, and large quantities may explode.

Mannitol hexanitrate is manufactured by dissolving mannitol in a fivefold amount of nitric acid (d = 1.51) at a temperature below 0 C. Then a tenfold quantity of concentrated sulfuric acid (d = 1.84) is added to the solution. Fine crystals of the product are precipitated which are separated on a vacuum filter. The product is washed with cold water, neutralized by means of dilute sodium bicarbonate solution, and once again washed. Then the mannitol hexanitrate is dissolved in hot ethanol, a stabilizer, diphenylamine, added and the product crystallized.

Mannitol hexanitrate can be used as a secondary charge in some detonators, instead of tetryl. It is used in detonators in which the primary initiator is diazodinitrophenol. It has also been used in detonators with tetrazine. In addition, mannitol hexanitrate is used for medical purposes instead of nitroglycerine, since its physiological effect is slower and longer lasting.[0477,1433,2171]

2. TOXICITY

Mannitol hexanitrate can cause dilation of blood vessels, headaches, nausea, vomiting, methemoglobinemia, cyanosis, reduced blood pressure,

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central nervous system depression and with larger quantities, coma and respiratory paralysis.[0766] Except by ingestion, it is not likely that workers will receive sufficient mannitol hexanitrate to cause a toxic reaction. The solubility in water and vapor pressure are both low and the inhalation or skin absorption of appreciable quantities of mannitol hexanitrate vapor is unlikely. Therefore, a Threshold Limit Value (TLV) has not been set for mannitol hexanitrate.

3. OTHER HAZARDS

Mannitol hexanitrate is a detonating agent that is so sensitive to heat, electrical discharge, impact, and friction that it undergoes detonation when subjected to a very mild electrical, mechanical or thermal shock from a spark, flame, or percussion.[0766] Old or contaminated mannitol hexanitrate has enhanced sensitivity and presents an extreme hazard. It must be handled with the greatest of care by an experienced ordnance disposal team.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Mannitol hexanitrate is classified by DOT as an Explosive, Class "A" and classified by the Army as a Class 9 Explosive. Its principle use is as a secondary charge in detonators and in blasting caps designed to be ignited by a fuse. It is stored dry, instead of being wet with water as are most other initiators.[0477] Because of its explosive nature, it is recommended that no mannitol hexanitrate be released to the environment.

5. EVALUATION OF CURRENT AND NEAR FUTURE MANNITOL HEXANITRATE DISPOSAL PROCESSES

Option No. 1 - Detonation

The only published method for disposal of scrap mannitol hexanitrate is by detonation. Mannitol hexanitrate in small bags may be transported to the demolition are. Several bags are removed from the transporting containers and carried to a destruction pit, placed in intimate contact with each other, and a blasting cap placed between the bags to initiate the mannitol hexanitrate. All remaining explosives should be kept behind a barricade with overhead protection during destruction operations. In the destruction operation appreciable NO_x will be released per unit weight of nitromannitol destroyed. If care is taken so that only small quantities of nitromannitol are destoryed at any one time in remote locations, the NO_x produced destroying the small quantities of mannitol hexanitrate will not create an excessive environmental hazard.[1147] The safety hazards of the disposal team involved in other methods of disposal exceed the environmental impact of the NO_x released by detonation of small quantities of the material.

Option No. 2 - Open Burning

Wastes contaminated with mannitol hexanitrate are currently disposed of by open burning in a remote demolition area. The waste, if not fully combustible, is covered with fuel oil, and ignited from a safe distance using a black powder squib. The safety procedures followed are similar to those employed when detonating mannitol hexanitrate. The safety hazards to the public and the disposal team involved in other methods of disposal exceed the environmental hazard created by the release of NO_x.

Research is required to establish adequate procedures for the safe and minimized environmental impact disposal of nitromannitol. A tentative concept for investigation is the use of sodium sulfide solution to "kill" the nitromannitol, followed by controlled incineration of the reaction products. The incineration equipment should be provided with appropriate scrubbing devices.

6. APPLICABILITY TO NAITONAL DISPOSAL SITES

The principle use of mannitol hexanitrate is as a secondary charge in detonators and in blasting caps designed to be initiated by a fuse. Except for a very small quantity that may be used in medicine, mannitol hexanitrate is stored at explosive manufacturing plants that have facilities for disposal of initiating agents. It is anticipated that waste mannitol hexanitrate will continue to be disposed of at these facilities.

Nitromannitol wastes not destroyed at the manufacturing plants are candidates for National Disposal Sites, if the specific waste is safe to handle and transport. Research is required, as noted above, to establish minimized environmental hazard procedures for the safe disposal of nitromannitol and nitromannitol contaminated wastes. Until such procedures have been established, those cited under options No. 1 and No. 2 of Section 5 should be used.

It should be noted that aged or contaminated nitromannitol wastes represent an unpredictable extreme disposal hazard. If at all possible, aged and contaminated wastes should be processed for disposal using remote handling devices and adequate personnel protection clothing and blast shields. In all cases nitroannitol handling and transportation for disposal should be performed only by qualified demolition personnel, experienced in disposal of nitroglycerin our nitromannitol. If the team believes handling and transportation to be sufficiently low in hazard to the team and the public, transportation should be in a special bomb disposal box, on a vehicle especially equipped for the safe transport of primary explosives and only to the nearest satisfactory disposal site. If hazards to the team and public are excessive, disposal should be by detonation or burning* in a cleared area.

---

* Using the precautions noted in Option No. 2

7. REFERENCES

0474. Tomlinson, W. R., Jr. Revised by O. E. Sheffield. Properties of explosives of military interest. Technical Report No. 1740, Revision 1, Picatinny Arsenal. Apr. 1958. 348 p.

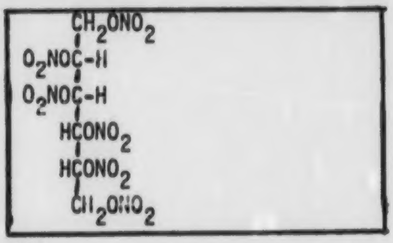
0766. Sax, N. I. Dangerous properties of industrial materials. 3d ed. New York, Reinhold Publishing Corporation, 1968. 251 p.

1147. Department of the Army and the Air Force, Military Explosives. TM9-1910, Washington, Apr. 1955. 336 p.

1433. Kirk-Othmer encyclopedia of chemical technology. 2d ed. 22 v. New York, Interscience Publishers, 1963.

2171. Urbanski, Todeusz. Chemistry and technology of explosives, v. III, Warszana Polish Scientific Publishers, 1967. Translated by Jurecki, Marian, New York, Pergamon Press. 714 p.

HAZARDOUS WASTES PROPERTIES WORKSHEET



$$\begin{array}{c} CH_2ONO_2 \\ | \\ O_2NOC\text{-}H \\ | \\ O_2NOC\text{-}H \\ | \\ HCONO_2 \\ | \\ HCONO_2 \\ | \\ CH_2ONO_2 \end{array}$$

H. M. Name Mannitol Hexanitrate

IUC Name Mannitol Hexanitrate

Common Names

Molecular Wt. 452(1)   Melting Pt. 112-113(2)   Boiling Pt. dec. 150 C

Density (Condensed) 1.73g/cc @ 20 ° C   Density (gas) @ °

Vapor Pressure (recommended 55 C and 20 C)

@ °   @ °   @ °

Flash Point °   Autoignition Temp. °

Flammability Limits in Air (wt %)   Lower   Upper

Explosive Limits in Air (wt. %)   Lower   Upper

Solubility

Cold Water Insoluble   Hot Water Insoluble   Ethanol 2.9g/100g at 13 C very soluble when not

Others: Ether 4g/100g at 9C

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in

ICC Classification Explosive, Class A   Coast Guard Classification Explosive, Class A

Comments

References (1) 0474

PROFILE REPORT

Mercuric Fulminate (Fulminate of Mercury) (533)

1. GENERAL

Mercury fulminate, $Hg(ONC)_2$, is a salt of an acid that is too unstable to exist in the free state. It is white when pure. As manufactured, the commercial product is only 98 to 99 percent pure and is grayish. $Hg(ONC)_2$ forms octahedral crystals, usually truncated, which are soluble in water to the extent of 0.01 percent at 15 C and only slightly soluble in cold ethanol. It can, therefore, be stored under water or under a mixture of equal amounts of ethanol and water to reduce the danger of explosion.

Mercury fulminate is more sensitive to impact than lead azide and lead styphnate and has the same sensitivity as diazodinitrophenol. Mercury fulminate is more sensitive to heat and friction than lead azide and lead styphnate and has a higher explosion temperature test value (210 C) than diazodinitrophenol and tetracene. The relatively poor stability of mercury fulminate is its most disadvantageous characteristic and the main reason it has largely been replaced with other initiators such as lead azide. When maintained for relatively short periods of time at 85 C, it explodes. Mercury fulminate deteriorates with age, chiefly to a nonexplosive solid rather than to gaseous products. When its purity has been reduced to about 92 percent, the initiating efficiency is practically destroyed.[0474,1147]

Mercury fulminate is manufactured in relatively small batches. Mercury is dissolved in nitric acid and this solution is poured into 90 percent ethanol, resulting in the evolution of white fumes followed by red fumes and subsequent appearance of fulminate crystals. The reaction mixture is diluted with water and the crystals repeatedly washed, by decantation, until all acid is removed.[0474,1147,2171]

The chemical/physical properties for mercury fulminate are summarized on the attached worksheet.

2. TOXICOLOGY

Mercury and its compounds are of recognized toxicity, but the handling of mercury fulminate is not unduly hazardous from a toxicity viewpoint. Because it is sparingly soluble in water, its toxicity through contact with the skin is insignificant. If taken orally, it is poisonous. Its dust should not be inhaled, and it has been recommended that the air in loading plant buildings should contain not more than 0.1 milligram of mercury fulminate per cubic meter for workers exposed for an 8-hr day five days per week.[1147]

3. OTHER HAZARDS

Mercury fulminate is a primary (initiating) explosive that is so sensitive to friction, heat, impact, and electrical discharge that it undergoes detonation when subjected to very mild thermal, mechanical, or electrical shock by flame, percussion, or electric discharge. When dry, it reacts to produce non-explosive products rapidly with aluminum and magnesium, slowly with copper, zinc, brass and bronze, and not at all with iron and steel. When wet, it reacts to produce non-explosive products immediately with aluminum and magnesium, rapidly with copper, zinc, brass and bronze and not at all with iron and steel. Mercury fulminate readily decomposes in the presence of light.[1147]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

The sensitivity of mercury fulminate to shock and friction, as with most initiating agents, requires that all scrap and waste from preparation and purification be maintained wet for destruction. Mercury fulminate is packaged wet for storage or shipment. Packaging is accomplished by placing approximately 25 lb, wet with 20 percent water or a 50:50 water-alcohol mixture for low temperature storage, in a duck- or rubberized-cloth bag covered with a cap of the same material. The bag is then tied securely. Not more than six such bags are placed in a large bag of the same material. The large bag is tied and placed in the center of a watertight metal or wooden barrel, drum, or keg lined with a heavy close-fitting jute bag. The large bag containing mercury fulminate is surrounded with well-packed sawdust that has been saturated with water or water-ethanol mixture. The bag forming a liner is sewn closed before closing the barrel, drum, or keg. Not more than 150 lb, of initiating explosive is permitted in a single container. It is shipped wet under DOT regulations for an Explosive Class A.[1147] It is stored under DOD regulation for an Explosive Class 9, Group M (wet).[0474]

Waste streams from the manufacture of mercury fulminate are of three types:[2169] (1) spent liquors decanted from above the product; (2) sediment removed from the mercury fulminate by washing (slime); and (3) condensed vapors.

Waste stream (1) contains about 3 percent of dissolved material composed of 90 to 96 percent oxalic acid and 3 to 6 percent mercurous nitrate. The mercury in this stream is recovered by addition of 1 liter of hydrochloric acid to 50 liters of solution followed by the addition of zinc to precipitate metallic mercury. The mercury in waste stream (1) is sometimes recovered by the addition of lime to form a precipitate, followed by solution of the precipitate in hydrochloric acid, and recovery of metallic mercury by electrolysis or by the addition of zinc. The residual solution is treated with lime, the precipitate sent to a landfill, and the solution discharged into a sewer or stream.

Waste stream (2), slime, has a similar composition to waste stream (1) and is treated in the same manner.

Waste stream (3), condensed vapors, is chiefly ethanol and is purified for reuse by distillation over sodium.

Excess or contaminated mercury fulminate is treated in the manner described in Section 5.

Because mercury fulminate is a high explosive, it is recommended that no mercury fulminate be released to the environment outside the boundaries of a manufacturing plant. Present goals in the United States are no mercury in waste streams. It is recommended that sodium borohydride reduction and special ion exchange methods for the removal of last traces of mercury (described in Profile Report on Mercuric Cyanide, [254]) be evaluated for use on mercury fulminate manufacturing operation waste streams.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Destruction of mercury fulminate by detonation in an open burning area is a procedure employed currently for disposal[2170] which is not recommended because of the possible contamination of the environment with mercury. The recommended wet method for decomposition of mercury fulminate is by the addition of at least 10 times its weight of a 20 percent solution of sodium thiosulfate. Some cyanogen gas may be evolved and an alkaline scrubber is required to prevent emission of $(CN)_2$.[0474,1147] The HgS precipitate obtained should be coagulated by boiling, removed by filtration, and recycled to a mercury smelter for recovery of mercury.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Mercury fulminate is not at present in general use as an initiating agent. Plants manufacturing mercury fumminate for use in ammunition or detonators have facilities for the disposal of the material discharged in waste streams, as scrap, or as excess material. Mercury fulminate which is not processed for disposal at such manufacturers' facilities is a candidate for National Disposal Sites if the specific waste involved can be handled and transported safely. The disposal process to be employed at National Disposal Sites should be that recommended in Section 5. Surplus, scrap or obsolete materials containing mercury fulminate should only be handled by qualified ordnance demolition personnel experienced in disposal of mercury fulminate. In the event that hazards to the disposal team and the public, due to handling and transport to the nearest National Disposal Site, are deemed excessive by the demolition team, the material should be disposed of by detonation in a cleared area. Transportation of any wastes containing or contaminated with mercury fulminate should be in a vehicle properly equipped for safe transport of primary explosives, and only to the nearest satisfactory disposal site. The contaminated waste or scrap fulminate should be transported wet.

7. REFERENCES

0474. Tomlinson, W. R., Jr., revised by O. E. Sheffield. Properties of explosives of military interest, Technical Report No. 1740, Rev. 1, Picatinny Arsenal. Apr. 1958. 348 p.

2169. Fedoroff, B. T. Encyclopedia of explosives and related items, v. 1. Picatinny Arsenal, 1960. 692 p.

2170. Ordnance Corps, Department of the Army, Ordnance Safety Manual, ORDM-7-224, Washington. 1951.

2171. Urbanski, Todeusz. Chemistry and technology of explosives, V.III, Warszawa, Polish Scientific Publishers, 1967. Translated by Jurecki, Marian, New York, Pergamon Press. 714 p.

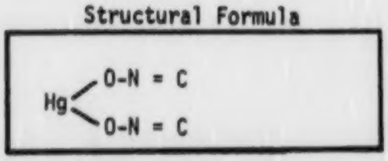
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Mercuric Fulminate

IUC Name

Common Names Fulminate of mercury, mercury fulminate

Structural Formula



Molecular Wt. 285 (1) Melting Pt. 210 C explodes (1) Boiling Pt.

Density (Condensed) 4.43g/cc @ 23 C Density (gas) @

Vapor Pressure (recommended 55 C and 20 C) (1)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water 0.07g/100g at 12 C (1) Hot Water 0.18g/100g at 49 C (1) Ethanol slightly soluble (1

Others: soluble in aqueous NH_4OH or KCN and in pyridine (1)

Acid, Base Properties

Highly Reactive with concentrated hydrochloric acid (1)

Compatible with

Shipped in

ICC Classification Explosive, Class A (1) Coast Guard Classification Explosive, Class A (1)

Comments

References (1) 0474

PROFILE REPORT

Potassium Dinitrobenzfuroxan(KDNBF)(536)

1. GENERAL

KDNBF is the potassium salt of 4,6-dinitrobenzfuroxan and normally occurs as golden orange plates which explode at 210 C. KDNBF is used as a primary initiating explosive. First step in the preparation is the reaction of o-nitroaniline and alkaline sodium hypochlorite to produce benzfuroxan. The benzfuroxan is then dissolved in 6 parts of 96 percent sulfuric acid and nitrated at 5 to 20 C with a 4 to 1 sulfuric-nitric acid mixture. The salt is prepared by neutralization of the 4,6-dinitrobenzfuroxan. The product is purified by recrystallization from hot water.[0474]

The physical/chemical properties are summarized in the attached worksheet.

2. TOXICOLOGY

KDNBF is not considered very toxic, but since it is an aromatic nitro-compound and is somewhat soluble in water, inhalation and skin contact must be avoided. Continued skin contact or ingestion will probably cause a decrease in blood pressure and large doses could cause dyspnea and convulsions. A Threshold Limit Value (TLV) has not been established for KDNBF.[0225]

3. OTHER HAZARDS

KDNBF is a primary initiating explosive that is so sensitive to heat, impact, and friction that it undergoes detonation when subjected to very mild thermal or mechanical shock by flame or percussion. It explodes when heated to 210 C.[0474]

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4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

KDNBF is stored dry and handled in accordance with DOD regulations for a Class 9, Group M Explosive and is classified by DOT as an Explosive, Class A.[0474] Waste KDNBF is found in recrystallization and wash waters which are collected in sumps, and evaporated. The recovered KDNBF is packaged for disposal as required for a Class 9, Group M Explosive.[2170,2230]

5. EVALUATION OF CURRENT AND NEAR FUTURE KDNBF DISPOSAL PROCESSES

Detonation has been used as the disposal method for packaged KDNBF. With this method several bags of KDNBF are carried to a remote destruction pit, placed in intimate contact with each other, and blasting caps placed between the bags to initiate the KDNBF. Remaining explosives must be kept behind a barricade with overhead protection during the destruction operations. Personnel must be behind a similar barricade.[1174,2170,2230] This process is satisfactory only for small quantities of KDNBF but provides a potential NO_x pollution problem when large quantities are detonated.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

The major use of KDNBF is as a primary explosive in military ammunition. The techniques currently under development which utilize controlled incineration, a rotating kiln equipped with alkaline scrubbing towers, is satisfactory for safe disposal of KDNBF fed to the kiln as a slurry in a water. The slurry contains about 3 parts of water to one part of KDNBF. The disposal system operates under an induced draft. Ammunition manufacturing plants and ammunition storage depots have facilities for disposal of KDNBF and other highly sensitive explosives. KDNBF scrap and KDNBF contaminated water disposal at these manufacturing plants and storage depots is a candidate for disposal at National Disposal Sites, if the specific waste can be handled safely and transported safely. The contaminated waste or scrap KDNBF should be transported wet, in a vehicle properly equipped for safe transport of primary explosives, and only to the nearest satisfactory disposal site. Surplus, scrap or obsolete materials containing

KDNBF should only be handled by qualified ordnance demolition personnel experienced in the disposal of primary explosives. If hazards to the disposal team and the public due to handling and transportation to the nearest National Disposal Site are deemed excessive by the demolition team, the KDNBF should be disposed of by detonation in a cleared area.

The process cited above, currently under development, is the only satisfactory process for disposal of moderate to large quantities of KDNBF.

7. REFERENCES

0225. American Conference of Government Industrial Hygienists. Threshold limits for 1971. Occupational Hazards, p 35-40, Aug. 1971.

0474. Tomlinson, W. R., Jr., revised by O. E. Sheffield. Properties of explosives of military interest, Technical Report No. 1740, Rev. 1, Picatinny ARsenal. Apr. 1958. 348 p.

2170. Ordnance Corps, Department of the Army. Ordnance safety manual, ORD7-224. Washington. 1951.

2230. Department of the Air Force. Explosive safety manual, AF Manual AFM127-100. Washington. Dec. 21, 1971.

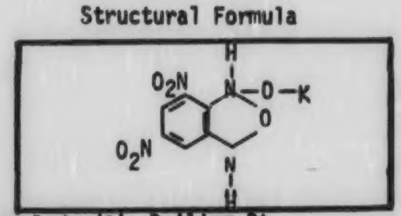
HAZARDOUS WASTES PROPERTIES WORKSHEET

H. M. Name Potassium dinitrobenzfuroxan

IUC Name ____________

Common Names KDNBF

Structural Formula



Molecular Wt.[1] 267(1)   Melting Pt.[2] 210 C explodes(1)   Boiling Pt. ____________

Density (Condensed) 2.21g/cc(1) @ 23 C(1)   Density (gas) ________ @ ______ ° ______

Vapor Pressure (recommended 55 C and 20 C)

________ @ ________ °   ________ @ ________ °   ________ @ ________ °

Flash Point ________ °   Autoignition Temp. ____ °

Flammability Limits in Air (wt %)   Lower ________   Upper ________

Explosive Limits in Air (wt. %)   Lower ________   Upper ________

Solubility

Cold Water 0.245g/100g at 30 C(1)   Hot Water slightly soluble(1)   Ethanol ________

Others: ____________

Acid, Base Properties ____________

Highly Reactive with ____________

Compatible with ____________

Shipped in bags(1)

ICC Classification explosive, Class A(1)   Coast Guard Classification Explosive, Class A(1)

Comments ____________

References (1) 0474

PROFILE REPORT

Silver Azide (538)

1. GENERAL

Silver azide is a very vigorous initiator, almost as efficient as lead azide. It is slightly hygroscopic; at room temperature in a damp atmosphere it picks up approximately 2 percent water. Like lead azide, silver azide decomposes under the influence of ultraviolet irradiation. If the intensity of the radiation is sufficiently high the crystals may explode. Silver azide, AgN_3, is manufactured in the same way as lead azide, in aqueous solution, by reaction between sodium azide and silver nitrate.[2171]

Silver azide has been used to a very limited extent in this country as an initiator of explosives, but is has found use as a detonator in foreign ammunition. There is no current known manufacturer of silver azide in the United States.[0474]

The physical/chemical properties of silver azide are summarized in the attached work sheet.

2. TOXICOLOGY

Silver azide can be absorbed into the body and the silver deposited in body tissue causing greyish pigmentation of the skin, a condition known as "argyria."[2169] The Threshold Limit Value (TLV) for silver azide dust for an 8-hour day, 5 days per week has not been established, but hydrazoic acid, which may be liberated upon acidification, has a TLV of 1 mg/M^3.[0095] For a detailed discussion on the toxicology of hydrazoic acid (528) the Profile Report on this compound should be reviewed.

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3. OTHER HAZARDS

Silver azide is a detonating agent that is so sensitive to heat, impact, electrical discharge, and friction that it undergoes detonation when subjected to a very mild thermal mechanical, or electrical shock by a spark, flame or percussion. Above its melting point, 250 C, it decomposes rapidly to silver and nitrogen. When silver azide has a very fine particle size, almost colloidal, it is safer to handle and is just as efficient and resistant to hydrolysis as coarse crystalline material. White silver azide is less affected by light than mercury or lead azide. If silver azide is precipitated from ammonium hydroxide, long, colorless crystals are formed which explode on breaking.[0474]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

In handling silver azide, contact with the skin and breathing of dust particles must be avoided. Dust must not be allowed to collect because of the explosive hazard. Discharge of electric sparks must be avoided.

Silver azide is classified by DOT as an Explosive, Class"A" and classified by the Army as a Class 9, Group M Explosive.[2170]

Though procedures are not published, it appears that waste silver azide can be destroyed in nearly the same manner as lead azide except that steps should be taken to recover the silver. The maximum concentrations of contaminants which may be released to the environment from waste disposal processes are as follows:

Contaminant and Environment	Concentration	Basis for Recommendation
Silver released, in any form, in water to streams or lakes.	0.05 ppm	Maximum recommended concentration discharged to a stream.[0536]
Nitrate and nitrite in water discharged to streams or lakes.	250 ppm	Maximum recommended concentration discharged to a stream.[0536]
pH	6.5 - 9.0	Recommended range of water discharged to a stream.

5. EVALUATION OF CURRENT AND NEAR FUTURE SILVER AZIDE DISPOSAL PROCESSES

Silver azide is not being manufactured at present, and therefore, specific disposal procedures have not been published. With some modification, the procedures used for the disposal of lead azide can be employed. Processes that can be used for the disposal of silver azide are briefly discussed in the following paragraphs with recommendations as to adequacy.

Option 1 - Detonation

The Ordnance Safety Manual recommends detonation as the best method for disposal of all initiating explosives.[2170] In the use of this procedure, bags containing the explosive should be kept wet while being transported to the demolition area. Several bags are removed from a container and carried to a destruction pit, placed in intimate contact with each other, and a blasting cap placed between the bags to initiate the explosives. All remaining explosives should be kept behind a barricade with overhead protection during destruction operations. In the use of this method, the silver present cannot be recovered, but will be lost to the soil in the demolition area. This method is not environmentally acceptable and should not be used unless the hazards of transportation and handling for disposal via the technique of Option 2 outweigh the ecological impact of detonation.

Option 2 - Oxidation with Nitrous Acid

Silver azide can be destroyed by oxidation with nitrous acid. This process involves wetting the silver azide with 500 times its weight of water, slowly adding 12 times its weight of 25 percent sodium nitrite, stirring, and then adding 14 times its weight of 36 percent nitric acid.[0474] Any NO_x fumes evolved should be removed by scrubbing the evolved gases with an alkaline solution. After letting the mixture stand for 16 hrs, the silver present should be recovered by electrolysis. Before discharging the silver-stripped decomposition solution, the pH should be adjusted with lime or caustic to 6.0 to 9.5 and the neutralized solution diluted to a nitrate and nitrite concentration of 250 ppm or less.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Silver azide waste, and silver azide contaminated wastes are candidates for National Disposal Sites if the specific waste can be handled and transported safely. The silver azide waste should be transported wet, in a vehicle properly equipped for transport of primary explosives, and only to the nearest satisfactory disposal site. The disposal process to be employed should be Option 2 (Section 5). Silver azide wastes should be handled only by qualified ordnance demolition personnel experienced in handling either silver azide or lead azide. If hazards to the disposal team and the public from transportation to the nearest National Disposal Site are deemed too high, or if the silver azide is suspected of being contaminated with copper azide, the waste should be destroyed by detonation in a cleared area.

7. REFERENCES

0474. Tomlinson, W. R. Jr., revised by O. E. Sheffield. Properties of explosives military interest. Technical Report No. 1740, Rev. 1. Apr. 1958.

0536. Water quality criteria. Report of the National Technical Advisory Committee to the Secretary of Interior. Washington, Federal Water Pollution Control Administration. Apr. 1, 1968. 234 p.

0095. Laboratory waste disposal manual. (Revised as of May 1970). Washington, Manufacturing Chemists Association. 1970. 175 p.

2169. Fedoroff, B. T. Encyclopedia of explosives and related items. V.1. Dover, Picatinny Arsenal. 1960. 692 p.

2170. Ordnance Corps, Department of the Army. Ordnance safety manual ORDM-224, Washington, 1951.

2171. Urbanski, Todeusz, Chemistry and technology of explosives, V.III. Warszawa, Polish Scientific Publishers, 1967. Translated by Jurecki, Marian, New York, Pergamon Press. 714 p.

HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Silver azide

IUC Name Silver azide

Common Names ______

Structural Formula

AgN_3

Molecular Wt. 149.9(1)

Melting Pt. 250 C (1)

Boiling Pt. 297-300 C explodes (1)

Density (Condensed) 4.8 g/ml @ 25 C (1)

Density (gas) ______ @ ______

Vapor Pressure (recommended 55°C and 20°C)

______ @ ______ ______ @ ______ ______ @ ______

Flash Point ______

Autoignition Temp. ______

Flammability Limits in Air (wt %) Lower ______ Upper ______

Explosive Limits in Air (wt. %) Lower ______ Upper ______

Solubility

Cold Water 3.9×10^{-5} mg/l at 17 C (1)

Hot Water ______

Ethanol slightly soluble (1)

Others: ______

Acid, Base Properties ______

Highly Reactive with ______

Compatible with ______

Shipped in wet with water or 50:50 water ethanol in bags.(1)

ICC Classification explosive, Class "A" (1)

Coast Guard Classification Explosive "Class A" (1)

Comments ______

References (1) 2169

PROFILE REPORT

Tetrazene (1-[5-tetrazolyl]-4-guanyltetrazene hydrate)(542)

1. GENERAL

Tetrazene is a pale-yellow, fluffy, crystalline solid that is prepared by adding sodium nitrite to a solution of 1-aminoguanidine hydrogen carbonate in dilute acetic acid at 30 C. After 24 hours the precipitated tetrazene is collected on a filter, washed thoroughly with water and alcohol, and dried at room temperature.

When exposed to a flame, tetrazene undergoes a mild explosion producing a large amount of black smoke. Its ignition temperature is much lower than that of mercury fulminate, although the two compounds have the same order of sensitivity to impact. Tetrazene does not initiate TNT or tetryl, but detonates uncompressed PETN. The ease of ignition, high heat of explosion, and the large volume of gaseous products given off during explosion give tetrazene its practical value as an ingredient for priming compositions. Tetrazene is relatively stable below 75 C but at 100 C it undergoes extensive decomposition.

The fact that tetrazene does not easily pass from burning to detonation makes tetrazene unsuitable for detonators and its application is thus limited to ignition caps, where even 2 percent in the composition results in improved uniformity of percussion and friction sensitivity and makes it suitable as a sensitizer for friction compositions.[0474,1147,1433,2171]

The physical/chemical properties for tetrazene are summarized in the attached work sheet.

2. OTHER HAZARDS

Tetrazene is an explosive that is so sensitive to electrical discharge, impact, friction and heat that it undergoes detonation when subjected to a very mild thermal, mechanical or electrical shock by a spark, flame or percussion. It has a lower explosion temperature (154 C) than most other initiating agents. It is its ease of ignition that renders it useful in priming compositions along with lead azide in explosive rivets. It is as sensitive to impact as mercury fulminate and diazodinitrophenol.

3. DEFINITION OF ADEQUATE WASTE MANAGEMENT

In the manufacturing process, waste tetrazene from precipitation and washing operations is collected in settling tanks for treatment by the process described in Section 4. Excess tetrazene is also disposed of in the same manner. Waste tetrazene should be kept wet until treated.[1147,2171]

There is no standard grade of tetrazene for military use, but the handling and storage of tetrazene is the same as for most initiating agents. It is packaged for storage or shipment wet with water. If shipment or storage under low temperature conditions is anticipated, a mixture of equal weights of water and ethanol is used. Up to 25 lb of tetrazene is placed in a bag with 20 percent liquid. Six such tied bags are placed in a large bag and then the large bag is placed in a waterproof container along with wet sawdust. Not more than 150 lb of tetrazene is permitted in a single container.

Tetrazene is shipped wet under DOD regulations for an Explosive, Class A. It is covered by DOD regulations for an explosive with a sensitivity of Class 9K Group M.[0766,1147,2230]

Because tetrazene is a sensitive explosive, it is recommended that no tetrazene be released to the environment.

4. EVALUATION OF CURRENT AND NEAR FUTURE TETRAZENE DISPOSAL PROCESSES

The processing options for the disposal of tetrazene are briefly described in the following paragraphs tegether with recommendations as to adequacy. Because of the explosive hazard, it is recommended that only personnel trained in handling initiating agents perform the disposal operations.

Option 1 - Treatment with Steam

Tetrazene in sumps associated with its manufacture and excess wet tetrazene are usually decomposed by passing steam into water containing tetrazene crystals. As the temperature of the solution reaches the boiling point, the tetrazene decomposes with the liberation of two molecules of nitrogen per molecule of tetrazene. The products of the decomposition may be sent to a sewage treatment plant. This process is satisfactory and is recommended in all literature reviewed.[0474,1147,2230]

Option 2 - Treatment with Aqueous Sodium Hydroxide

On hydrolysis of tetrazene with 10 percent sodium hydroxide in water, ammonia, cyanamide and triazonitroaminoguanidine are produced. This method, though satisfactory, is not aften used because the process is more complex than the one described under Option 1. In this process, the sodium hydroxide in the reacting solution must be neutralized before discharging to a sewer.[1147]

5. APPLICABILITY TO NATIONAL DISPOSAL SITES

The manufacture and use of tetrazene is limited principally to those plants manufacturing ignition caps and explosive bolts. Such plants are expected to use only small quantities of tetrazene, and have facilities for the disposal of tetrazene waste and tetrazene-contaminated waste. Tetrazene wastes which are not disposed of at the manufacturing plants are candidates for National Disposal Sites if the specific waste can be handled and transported safely. Tetrazene wastes should be transported wet, in a vehicle properly equipped for transportation of primary explosives and only to the nearest satisfactory disposal site, the disposal process to be employed at National Disposal Sites should be Option 1 (Section 4). Scrap and contaminated wastes should be handled only by qualified ordnance personnel, experienced in disposal of tetrazene. In the event that hazards to the team and the public from handling and transportation to the nearest National Disposal Site are deemed excessive by the disposal team, the tetrazene waste should be destroyed by detonation in a cleared area.

6. REFERENCES

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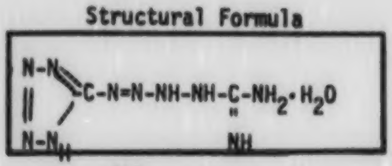
HAZARDOUS WASTES PROPERTIES
WORKSHEET

H. M. Name Tetrazene

IUC Name 1-(5-tetrazolyl)-4-guanyltetrazene hydrate

Common Names tetracene

Structural Formula



Molecular Wt. 188(1) Melting Pt. 140-160 C explodes(1) Boiling Pt.

Density (Condensed) 1.05 @ 3000 psig(1) Density (gas) @

Vapor Pressure (recommended 55 C and 20 C)

@ @ @

Flash Point Autoignition Temp.

Flammability Limits in Air (wt %) Lower Upper

Explosive Limits in Air (wt. %) Lower Upper

Solubility

Cold Water insoluble(1) Hot Water insoluble at 100 C(1) decomposes Ethanol insoluble(1)

Others: insoluble, CCl_4, benzene, ether, soluble - HCl (1)

Acid, Base Properties

Highly Reactive with

Compatible with

Shipped in bags, wet

ICC Classification Explosive, Class A(1) Coast Guard Classification Explosive, Class A (1)

Comments

References (1) 0474

APPENDIX B - NUCLEAR PROFILE REPORTS

PROFILE REPORT

Carbon-14, Cobalt-60, Iridium-192, Radium-226

1. GENERAL

Introduction

These four radionuclides are representative of the radioisotopes of commercial interest which are generally produced, distributed, and used by the private sector of our economy. In general these radioactive materials are not subject to federal regulations. This is in contrast to the complete control exercised by the Atomic Energy Commission over source, byproduct, and special nuclear materials. Most states have developed some type of program to control radiation exposure from radiation sources not subject to federal authority and 22 states have assumed some of the control over these radioactive materials. However, many states have virtually nonexistent or totally inadequate programs and individuals can still purchase radium without proof of competence to handle it safely. It is interesting to note that two-thirds of the companies selling radium devices are located in non-agreement states and account for 91 percent of the total devices sold.[2296]

Radium-226 is a naturally occurring radionuclide first discovered in 1898. It has the longest history of use of any radioactive material and is also one of the most hazardous radionuclides. The ingestion of the luminous dial paint prepared from radium-226 was the cause of death of many of the early dial painters before the hazard was fully understood. Much of what is known of the biological effects of ionizing radiation on man is based on the effects of radium ingested by these early watch dial painters. It is estimated that over 3 million timepieces containing radium are sold annually and the exposure to the total population is probably greater than that from all other consumer products containing radioactive material. A comparison of the estimated annual radiation dose received by the critical organs from a wrist watch containing 0.15 microcuries of radium-226 with the International Commission on Radiological Protection (ICRP)[0563] annual limit for that body part is attached (Table 1).

Radium-226 has a half-life of 1,602 years and decays by the emission of high energy, 5.68 Mev alpha particles. Radium-222 eventually decays to lead and its decay chain is attached.

Carbon-14, cobalt-60, and iridium-192 are produced in nuclear reactors by the bombardment of a target material with neutrons. Their principal use is in the fields of nuclear medicine, radiation detection and control equipment, and in nuclear power sources. Carbon-14 has a half-life of 5,730 years and emits only a 0.155 Mev beta particle. Cobalt-60 has a half-life of 5.3 years and emits both beta and gamma particles. It decays by the emission of a 0.319 Mev beta particle to form stable nickel-60. Iridium-192 is both a beta and gamma emitter and has a half-life of 74.2 days.

Manufacture

Radium-226 is a daughter of uranium-238 and is found to occur naturally in the earth's surface. Carbon-14, cobalt-60, and iridium-192 are produced by the bombardment of a target material with neutrons. This is usually performed in a nuclear reactor. Carbon-14 is produced by the neutron bombardment of nitrogen-14. Cobalt-60 is produced from cobalt-59 and iridium-192 is produced from iridium-191.

Uses

Radium-226 has been and still is used in a wide variety of products and applications. In the past 10 years there has been a decrease in radium usage made possible by the increased availability and acceptance of use of other less hazardous radioactive materials. Radium-226 is used in producing timepieces, electron tubes, record player brushes, gauges, fire detectors, and in various self-luminous products. It is used in medicine for the treatment of tumors, superficial skin lesions, lymphoid tissue, and other diseases. It is estimated that 330 curies of radium-226 contained in 50,000 sources are used in medical applications at 2,300 facilities which provide approximately 85,000 medical treatments per year.[2296]

Carbon-14 is used in medicine to study metabolic diseases, in radioisotope gauges, and has been widely used to date such materials as wood and archeological specimens. Iridium-192 is widely used in the field of medicine in radiographic units. Cobalt-60 is used in isotopic power devices, in teletherapy units to treat cancer, and in radiation processing applications Presently, there are approximately 1,830 cobalt-60 teletherapy units in use with each unit containing about 3 thousand curies of cobalt-60.[2151]

Sources and Types of Wastes

In almost all applications, these materials are used in the solid form. They are generally used as a sealed source and the material is retained within the encapsulating material. When radium-226 is used in self-luminous compounds, it is retained within the crystalline radium salt; however, there is some release of radium from luminous compounds. These materials are generally distributed throughout the country and can be found in hospitals, commercial facilities, and in households.

Physical and Chemical Properties

The physical and chemical properties of carbon-14, cobalt-60, iridium-192, and radium-226 are included in the attached worksheets. Carbon forms a vast number and variety of compounds with hydrogen, oxygen, nitrogen, and other elements. Cobalt is a brittle, hard material that resembles iron and nickel. Iridium is a metal of the platinum family. It is the most corrosion-resistant metal known and is the second heaviest known element. Radium is an alkaline metal that acts like calcium and barium chemically. It reacts with nitrogen and is mainly used in the form of salts.

2. RADIATION HAZARD

Radium-226 is one of the most hazardous radioactive materials known. Radium-226 replaces calcium in the bone structure and is a source of irradiation to the blood-forming organs. This , along with its long half-life (1,602 years) and high radiation energies, places it in the highest radiotoxicity group. It also has the longest history of use of any radioactive material, and most of the standards for the effects of ionizing radiation on man are based on this material. Carbon-14, cobalt-60 and iridium-192 are moderately dangerous radioactive materials.

The effects of their radiation exposure are primarily dependent on the amount of radiation and the portion of the body affected. The effects of acute whole-body radiation exposure are: (1) 0 to 25 rem, no detectable clinical effects; (2) 25 to 200 rem, delayed effects and possible shortened life expectancy of 1 percent; (3) 200 to 600 rem, possible premature death; (4) greater than 600 rem, death. These effects are for a single large dose of radiation or a series of substantial doses in a short interval of time to the total body. The dose delivered to a particular body organ following the inhalation of 1 microcurie of each of these radionuclides is attached (Table 3). For radium-226 the dose delivered to the bone is 300 rem following the inhalation of 1 microcurie (1.01 micrograms). The dose delivered to the bone following the injection of 1 microcurie into the body via a wound is 1,000 rem.

Standards for prolonged exposure over a fifty year period have defined the single dose limit in terms of the maximum permissible dose accumulated in a period of 13 weeks. The whole body exposure limit is 3 rem per quarter and the accumulated dose limit is 5(N - 18), where N is the individual's age in years. Limits for the thyroid, bone, and other organs have also been defined. Values of the total body burden for each radionuclide required to produce the maximum permissible dose rates defined above have been compiled.[0563] For radium-226 and carbon-14 the critical organ is the bone and the maximum permissible body burden is 0.1 and 300 microcuries, respectively. For cobalt-60 the critical organ is the total body and the maximum body burden is 10 microcuries. For iridium-192 the critical organ is the kidney and the maximum body burden is 6 microcuries.

3. OTHER HAZARDS

Besides its radiation hazard carbon is not very toxic. In the form of dust it can cause irritation of the eyes and mucous membranes. The toxicity of cobalt is also low. It can produce dermatitis and is slightly irritating to the skin. The toxicity of iridium is unknown even though soluble iridium compounds are said to be toxic.[0766] Radium's main hazard is its radioactivity. The fire and explosive hazard of the above materials is moderate.

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, Transportation

Since these radionuclides are hazardous to man by inhalation, ingestion, or direct radiation exposure, great care must be exercised in their handling. Handling must be set up to prevent excessive exposure to personnel and, in fact, to prevent any unnecessary exposure. Special procedures and adequate radiation shielding are required in their handling. Radium-226 is an alpha emitter. These alpha particles have little penetrating power and can be stopped by a sheet of writing paper. The beta particles emitted by carbon-14, cobalt-60, and iridium-192 range in energy from 0.16 to 0.67 Mev and cannot penetrate more than 0.015 to 0.085 inch of water. The gamma radiation emitted by cobalt-60, iridium-192 and radium-226 is highly penetrating and high-density shields, such as lead, are required to stop the radiation. For cobalt-60 which emits high energy gamma rays (1.33 Mev), approximately 3.5 inches of lead or 20 inches of concrete are required to reduce its radiation by a factor of 100. To detect and control personnel exposure to their radiation all persons working with this material should wear an external dosimetry device. The commonly used devices are the film badge and the thermoluminescent dosimeters (TLD).

Large quantities of these materials should be stored in controlled reservations in specially constructed containers or storage bins. They should be protected by both a primary and a secondary containment barrier. Special monitoring systems and proper warning signs should be located in the general area of the storage facility. Special precautions are required in the storage of radium-226 since approximately one gram of radium produces about 0.001 milliliter of radon gas per day. Thus, stored radium should be vented to prevent the build-up of radon gas.

Radium-226 is classified as a transport group I radionuclide, cobalt-60 and iridium-192 are classified as a transport group III radionuclide, and carbon-14 as a transport group IV radionuclide by the Department of

Transportation. The rules and regulations governing their transportation are given in the Code of Federal Regulations (CFR) Title 14--Transportation, Parts 170 to 190.[2150] The radium-226 content is limited to 0.001 curies for a Type A package and 20 curies for a Type B package defined in 40CFR173. For cobalt-60 and iridium-192 these limits are increased to 3 and 200 curies. For carbon-14 the limits are 20 and 200 curies. The release rate of these materials is limited to zero under the specified accident conditions for Type A and B packages.[2150]

Disposal/Reuse

The disposal of these materials is governed by the AEC Manual Chapter 0524[0559] and 10CFR20.[2149] Two sets of standards have been established for the permissible radiation exposure in unrestricted areas. One is for the greatest dose received by an individual and the other for the average dose received by the general population. The standards for the safe release of these materials to the environment in an unrestricted area are contained in 10CFR20[2149] and their release should not exceed the concentrations in air and water listed in this report (Table 4). These release rates apply to an individual and their release may be limited if a suitable sample of the population is exposed to one-third the concentrations in air or water specified in this report (Table 4).

The disposal by release in a sanitary sewage system is limited to 0.1 microcuries of radium-226, 10 microcuries of cobalt-60, 100 microcuries of iridium-192, and 1,000 microcuries of carbon-14. The disposal by burial at any one location and time is limited to 100 times the above amounts.

The above regulations for the transportation, release, and disposal of these materials apply only to licensed materials. Radium and other accelerator-produced radionuclides are exempt from AEC control and their regulation and control is a State function. In some States the possession and use of these materials requires licensing and in others no license is required. Thus, the disposal, transportation, and use of these materials in some uses is not subject to the above regulations.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Option No.1-Land Burial. Land burial of carbon-14, cobalt-60, and iridium-192 wastes, in small concentrations, at approved sites that are acceptable from a geologic standpoint, is an acceptable means of disposal. Their concentration should not be in excess of 10^4 times the maximum permissible concentration for the general population in 10CFR20.[2149] All wastes to be disposed of should be in a solid form and encapsulated in a suitable container. The burial site design, geology, and hydrology should be in conformance with the criteria used in selecting and licensing the present commercial burial sites.[1423] This method of disposal is not considered satisfactory for the disposal of radium-226 since it has such an extremely long half-life and a high radiotoxicity.

Option No.2-Near-Surface Solid Storage. The disposal of solidified radium-226 wastes in engineered surface facilities offers the best immediate method for disposal of these wastes. The technology for these facilities has been developed and the wastes will be under surveillance and control and can be retrieved, should this be required. The wastes will be stored in steel vaults encased in concrete. The periodic replacement of the waste containers will be required due to the extremely long half-life of radium-226.

Option No.3-Salt Deposits. This method offers the greatest potential for the disposal of radium-226 wastes since bedded salt deposits are completely free of circulating ground waters. This method of disposal has been under study by the Oak Ridge National Laboratory since 1957, and in November of 1970 a committee of the National Academy of Sciences recommended that the use of bedded salt for the disposal of radioactive waste is satisfactory.[0733] The critical problem is the selection of a site that meets the necessary design and geological criteria. For radium-226 wastes the life of the mine must extend beyond several thousand years. Salt deposits should be considered for the disposal of radium-226 wastes at approved sites that are acceptable from a design and geological standpoint. In addition, a method of waste retrieval is required in the event the integrity of the site is destroyed.

To summarize, small concentrations of carbon-14, cobalt-60, and iridium-192 can be disposed of by land burial at approved sites. Since radium-226 is an extremely hazardous long-lived isotope, it should be disposed of in either salt deposits or near-surface engineered facilities.

6. APPLICABILITY TO NATIONAL DISPOSAL SITE

Carbon-14, cobalt-60, iridium-192, and radium-226 are candidates for a National Disposal Site due to their large commercial usage and high health hazard. The recommended process for the disposal of carbon-14, cobalt-60, and iridium-192 wastes, in small concentrations, is by land burial. The recommended processes for the disposal of radium-226 and large concentrations of the above radionuclides are:

Process	Order of Preference	Remarks
Near-surface solid storage	First choice	Demonstrated technology; waste under constant surveillance and control and can be retrieved.
Salt beds	Second choice	Affords permanent disposal without constant surveillance; further development required for a waste retrieval plan and location of an acceptable site.

7. REFERENCES

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HAZARDOUS WASTES PROPERTIES WORKSHEET

Name Carbon-14

Half-life 5730 Years

Type of Decay Negative Beta

Molecular Wt. 14

Melting Pt. 3550C

Boiling Pt. 4827C

Density 3.5 gm/cc

Specific Power

Specific Activity 4.46 curies/gm

Structural Formula

$_6C^{14}$

Solubility

Cold Water insoluble

Hot Water insoluble

Others: insoluble in acid and alkali

Decay Chain

$$\underset{(5730\ \text{years})}{{}_6C^{14}} \xrightarrow{B-} \underset{(\text{Stable})}{{}_7N^{14}}$$

Radiation Energy Level & Intensities

Beta: 0.155 Mev (100%)

Gamma: None

Shipping Regulations Classified as a transport group IV radionuclide by the Department of Transportation

Comments

References: (1) 0766
(2) 2150

HAZARDOUS WASTES PROPERTIES
WORKSHEET

Name Cobalt-60

Half-life 5.3 Years

Type of Decay Negative Beta

Structural Formula $_{27}Co^{60}$

Molecular Wt. 60

Melting Pt. 1495C

Boiling Pt. 2900C

Density 8.9 gm/cc

Specific Power 17.4 watts/gm

Specific Activity 1,130 curies/gm

Solubility

Cold Water insoluble

Hot Water insoluble

Others: soluble in acid

Decay Chain

$$_{27}Co^{60} \xrightarrow{B-} {}_{28}Ni^{60}$$

(5.3 years) (Stable)

Radiation Energy Level & Intensities

Beta: 0.319 Mev (100%)
Gamma: 1.332 Mev (100%)
1.173 Mev (100%)

Shipping Regulations Classified as a transport group III radionuclide by the Department of Transportation.

Comments

References: (1) 0766
(2) 2150

HAZARDOUS WASTES PROPERTIES
WORKSHEET

Name Iridium-192

Half-life 74.2 days

Type of Decay Negative Beta

Structural Formula

$_{77}Ir^{192}$

Molecular Wt. 192 Melting Pt. 2443C Boiling Pt. 4527C

Density 22.4 gm/cc Specific Power

Specific Activity 9.17×10^3 curies/gm

Solubility

Cold Water insoluble Hot Water insoluble

Others: insoluble in acid and alkali, slightly soluble in aqua regia

Decay Chain

$$_{77}Ir^{192} \xrightarrow{B-} {}_{76}Os^{192}$$

(74d) (Stable)

Radiation Energy Level & Intensities

Beta: 0.240 Mev (8%)
0.536 Mev (41%)
0.672 Mev (46%)

Gamma: 0.296 Mev (29%)
0.308 Mev (30%)
0.317 Mev (81%)
0.468 Mev (49%)
0.589 Mev (9%)
0.604 Mev (9%)
0.612 Mev (6%)

Shipping Regulations Classified as a transport group III radionuclide by the Department of Transportation

Comments

References: (1) 0766
(2) 2150

HAZARDOUS WASTES PROPERTIES
WORKSHEET

Name Radium-226

Half-life 1602 Years

Tyne of Decay Alpha

Molecular Wt. 226

Melting Pt. 700C

Boiling Pt. 1737C

Density 5 gm/cc

Structural Formula $_{88}Ra^{226}$

Specific Power 1.3×10^{-4} watts/gm

Specific Activity 0.99 curies/gm

Solubility

Cold Water reacts and evolves H_2O

Hot Water reacts and evolves H_2O

Others: reacts with acid

Decay Chain

$$_{88}Ra^{226} \xrightarrow{\alpha} {}_{86}Rn^{222}$$

(1602 years) (3.8 days)

Decays to Lead

Radiation Energy Level & Intensities

Alpha: 5.684 Mev (94%)
5.447 Mev (6%)

Gamma: 0.260 Mev (.007%)
0.186 Mev (4%)

Shipping Regulations Classified as a transport group I radionuclide by the Department of Transportation

Comments

References: (1) 0766
(2) 2150

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TABLE 1

ESTIMATED ANNUAL RADIATION DOSE FROM A WRIST WATCH CONTAINING 0.15 MICROCURIES OF RADIUM-226

Organ	Estimated Annual Dose millirem	ICRP Annual Limit For Body Part 0563 millirem
Skin of the wrist	4,800	7,500
Lens of eye	110	500
Blood-forming tissue	30	500
Gonads	10	500

TABLE 2
RADIUM-226 DECAY CHAIN

Nuclide	Name	Half-Life	Major Radiation
${}_{88}Ra^{226}$	Radium-226	1602 years	Alpha and gamma
${}_{86}Rn^{222}$	Radon-222	3.8 days	Alpha and gamma
${}_{84}Po^{218}$	Polonium-218	3.5 minutes	Alpha
${}_{82}Pb^{214}$	Lead-214	26.8 minutes	Beta and gamma
${}_{83}Bi^{214}$	Bismuth-214	19.7 minutes	Alpha, beta and gamma
${}_{84}Po^{214}$	Polonium-214	164 miroseconds	Alpha
${}_{82}Pb^{210}$	Lead-210	21 years	Beta and gamma
${}_{83}Bi^{210}$	Bismuth-210	5 days	Beta
${}_{84}Po^{210}$	Polonium-210	138 days	Alpha
${}_{82}Pb^{206}$	Lead-206	Stable	

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TABLE 3

CARBON-14, COBALT-60, IRIDIUM-192, AND RADIUM-226 DOSE TO A PARTICULAR BODY ORGAN FOLLOWING INHALATION OF ONE MICROCURIE OF THE NUCLIDE

Isotope	Form	Organ	Dose rem
Carbon-14	Insoluble	Lung	0.06
Carbon-14	Soluble	Bone	0.002
Cobalt-60	Insoluble	Lung	0.77
Cobalt-60	Soluble	Total Body	0.008
Iridium-192	Insoluble	Lung	0.27
Iridium-192	Soluble	Kidney	0.05
Radium-226	Insoluble	Lung	130
Radium-226	Soluble	Bone	300

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TABLE 4

CARBON-14, COBALT-60, IRIDIUM-192, AND RADIUM-226

ENVIRONMENTAL RELEASE RATES [2149]

Radionuclide	Form	Concentration in Air (microcuries/milliliter)	Concentration in Water (microcuries/milliliter)
Carbon-14	Soluble	1×10^{-7}	8×10^{-4}
Carbon-14	Submersion*	1×10^{-6}	--
Cobalt-60	Soluble	1×10^{-8}	5×10^{-5}
Cobalt -60	Insoluble	3×10^{-10}	3×10^{-5}
Iridium-192	Soluble	4×10^{-9}	4×10^{-5}
Iridium-192	Insoluble	9×10^{-10}	4×10^{-5}
Radium-226	Soluble	3×10^{-12}	3×10^{-8}
Radium-226	Insoluble	2×10^{-12}	3×10^{-5}

*Submersion means that values given are for submersion in an infinite cloud of gaseous material.

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PROFILE REPORT

Iodine-129, Iodine-131, Krypton-85, Xenon-133

1. GENERAL

Introduction

Iodine and the noble gases, krypton and xenon, are produced during the fission of uranium in nuclear reactors. They represent a potential source of environmental contamination since they are presently released to the environment during reprocessing of the nuclear fuels. Although the release rates at present reprocessing plants are low, the recovery and retention of these gases will be required in the near future due to the rapid rate of expansion of the nuclear power industry and the corresponding expansion in the nuclear fuel reprocessing industry. In addition to the anticipated growth in this industry, economic incentives exist for reducing fuel decay times prior to reprocessing. Present reprocessing plants handle 150-day decayed light water reactor fuel. With the introduction of the fast-breeder reactors it is economically desirable to reprocess the fuel after 30 days decay. The shortened decay period will increase the reprocessing plant off-gas handling requirements for the short-lived isotopes such as iodine-131 (8 days) and xenon-133 (5 days). The iodine-131 activity in 30-day-old reactor fuel is 36,000 times higher than it is in 150-day-old reactor fuel.

Of the fission-product halogens only the isotopes iodine-129 and iodine-131 are physiologically significant after 30 days of post-irradiation decay. The iodine-131 contents of reactor fuels are approximately 72,000 and 2 curies per metric ton of reactor fuel after decay times of 30 and 150 days respectively. The iodine-129 content is only about 0.03 curies per metric ton of reactor fuel. Even though the iodine-129 content in reactor wastes is low, it is significant since it has a half-life of

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17 million years compared to the iodine-131 half-life of 8 days. Iodine-129 and iodine-131 are also reconcentrated by biological processes in the food chain leading to man. This reconcentration occurs in the grass-cow-milk pathway to the thyroids of small children and man.

Krypton and xenon are both produced in significant quantities in nuclear reactors. These isotopes are chemically inert and once released they do not concentrate in body tissues. The various isotopes of krypton and xenon in reactor fuels are attached (Table 1). The only two isotopes of significance are krypton-85 and xenon-133. Krypton-85 has a half-life of 10.8 years, a moderate beta radiation energy, a low gamma radiation level, and a fission yield of 1.3 percent. Xenon-133 has a half-life of 5.3 days, a moderate beta and gamma radiation energy, and a fission yield of 6.6 percent.

The projected growth in production of these isotopes will parallel that of the civilian nuclear power program. Present projections indicate that the total installed capacity of nuclear power plants will grow by a factor of 60 between 1970 and 1985.[2148] The expected annual production of iodine-129 (Table 2) and the expected annual production and accumulated wastes of krypton-85 (Figure 1) from the civilian nuclear power program are included. Production figures for iodine-131 and xenon-133 are not included since due to their short half-life the amount present varies with the post-irradiation decay time.

Uses

Krypton-85 is used in the preparation of self-illuminating materials and devices. Its properties also make it useful in leak detection equipment, thickness gauges, and in gas chromatography. The fission product xenon, including xenon-133, which is essentially non-radioactive by the time it is recovered, is used in scintillation devices because it has a higher proportion of heavy isotopes of xenon than does naturally occurring xenon. Xenon is also used in the manufacture of light bulbs that have an extra long life. Iodine-131 is used in medical diagnosis and therapy and also in agricultural research. Since iodine-131 tends to concentrate in the thyroid, it is used in the treatment of hyperthyroidism and in treating congestive heart failure. Iodine-129, due to its long half-life, has very limited commercial use.

Sources and Types of Wastes

Iodine, krypton, and xenon are produced in nuclear reactors and are contained within the spent fuel elements. The spent fuel elements are removed from the reactor and processed for the recovery of usable fissionable materials. In the nuclear fuel reprocessing plants the majority of these radionuclides are released as gases during the dissolution of the fuel elements in the head-end process. They are also released in the venting of process vessels and in the treatment of liquid wastes. Iodine-129 and iodine-131 are released in the off-gas streams in the form of elemental iodine (I_2), hydrogen iodide, or as an organic iodide compound such as methyl iodide. Krypton and xenon are released in their elemental form and do not form compounds with other materials since they are chemically inert.

Physical and Chemical Properties

The physical and chemical properties of iodine, krypton, and xenon are included in the attached worksheets. Iodine is a member of the halogen group and is a solid at room temperature. Iodine is easily melted and vaporized and is a very powerful oxidizing agent. Iodine forms compounds with many elements, but is less active than the other halogens which displace it from iodide compounds. Krypton and xenon are members of the rare or inert gas group. These gases are characterized by their zero valence and are considered inert and unable to form compounds with other elements. Recently some compounds of these inert gases have been reported.

2. RADIATION HAZARD

Iodine, xenon, and krypton are moderately hazardous radioactive nuclides. Krypton and xeon are chemically inert and once released they do not concentrate in body tissues. Iodine does reconcentrate by the grass-cow-milk pathway to the thyroid.

The effects of their radiation exposure are primarily dependent on the amount of radiation and the portion of the body affected. The effects of acute whole-body radiation exposure are: (1) 0 to 25 rem, no detectable clinical effects; (2) 25 to 200 rem, delayed effects and possible shortened life expectancy of 1 percent; (3) 200 to 600 rem, possible premature death; (4) greater than 600 rem, death. These effects are for a single large dose of radiation or a series of substantial doses in a short interval of time to the total body. The dose delivered to a particular body organ following the inhalation of 1 microcurie of each of these radionuclides is attached (Table 3). For iodine-131 a dose of 25 rem is delivered to the thyroid following the inhalation of 15.6 microcuries (0.002 micrograms).

Standards for prolonged exposure over a fifty year period have defined the single dose limit in terms of the maximum permissible dose accumulated in a period of 13 weeks. The whole body exposure limit is 3 rem per quarter and the accumulated dose limit is 5(N - 18), where N is the individual's age in years. Limits for the thyroid, bone, and other organs have also been defined. Values of the total body burden for each radionuclide required to produce the maximum permissible dose rates defined above have been compiled.[0563] For iodine the critical organ is the thyroid and the maximum permissible body burden is 2 microcuries for iodine-131 and 9 microcuries for iodine-129.

3. OTHER HAZARDS

Besides its radiation hazard iodine is moderately toxic whereas krypton and xenon are only slightly toxic. Iodine contact with the skin can cause lesions and iodine vapor is intensely irritating to the eyes and mucous membranes. The recommended maximum allowable concentration of iodine in the air is 1 mg/cu. meter.[0766]

4. DEFINITION OF ADEQUATE WASTE MANAGEMENT

Handling, Storage, Transportation

Since these radionuclides are hazardous to man by inhalation, ingestion, or direct radiation exposure, great care must be exercised in their handling. Handling must be set up to prevent excessive exposure to personnel and, in fact, to prevent any unnecessary exposure. Special procedures and adequate radiation shielding are required in their handling. The beta particles emitted by iodine, xenon, and krypton are of moderate energy and cannot penetrate more than 0.1 inches of water. Their gamma radiation is highly penetrating and high-density shields, such as lead, are required to stop the radiation. To detect and control personnel exposure to their radiation all persons working with this material should wear an external dosimetry device. The commonly used devices are the film badge and the thermoluminescent dosimeters (TLD).

These materials should be stored in controlled reservations in specially constructed containers or storage bins. They should be protected by both a primary and a secondary containment barrier. Special monitoring systems and proper warning signs should be located in the general area of the storage facility.

Iodine-129 and iodine-131 are classified as a transport group III radionuclide and krypton-85 and xenon-133 are classified as a group IV radionuclide in the uncompressed state, at a pressure less than 14.7 psia, and as a group III radionuclide at pressures greater than 14.7 psia by the Department of Transportation. The rules and regulations governing their transportation are given in the Code of Federal Regulations (CFR) Title 49--Transportation, Parts 170 to 190.[2150] The transport group III radionuclide content is limited to 3 curies for a Type A package and 200 curies for a Type B package defined in 49CFR173. Their release rate is limited to zero under the specified accident conditions for Type A and B quantities.[2150]

Disposal/Reuse

The disposal of these materials is governed by the AEC Manual Chapter 0524[0559] and 10CFR20.[2149] Two sets of standards have been established for the permissible radiation exposure in unrestricted areas. One is for the greatest dose received by an individual and the other for the average dose received by the general population. The standards for the safe release of these materials to the environment in an unrestricted area are contained in 10CFR20[2149] and their release should not exceed the concentrations in air and water listed in this report (Table 4). These release rates apply to an individual and their release may be limited if a suitable sample of the population is exposed to one-third the concentrations in air or water specified in this report (Table 4).

The disposal by release in a sanitary sewage system is limited to 1 microcurie for iodine-129, 10 microcuries for iodine-131 and 1000 microcuries for krypton-85 and xenon-133.[2149] The disposal by burial at any one location and time is limited to 100 times the above amounts.

5. EVALUATION OF CURRENT AND NEAR FUTURE DISPOSAL PROCESSES

Iodine Recovery

Option No.1-Caustic Scrubbers. Iodine has been removed from gas streams in many applications by scrubbing with caustic solutions and reacting with silver nitrate impregnated on ceramic packing. Caustic scrubbers are effective in removing approximately 90 percent of the iodine in the off-gas streams and the silver nitrate towers remove about 99 percent of the remaining iodine. In general, caustic scrubbers are not effective in removing organic iodides, such as methyl iodide. Organic iodides can be effectively removed by using an aqueous scrubbing medium of mercuric nitrate in nitric acid if sufficient contact time is allowed for the relatively slow reaction between the absorbed organic iodide and mercury ion. In a large-scale plant with large gas flows they have limited applications. Caustic scrubbers are satisfactory for the removal of elemental iodine but not for organic iodides unless used in a secondary iodine removal system where gas flows are relatively low.

Option No.2-Activated Charcoal. Charcoal has been extensively used for the removal of elemental iodine from off-gas streams. Elemental iodine is readily trapped from air streams by activated charcoal, even at relative humidities approaching saturation. Iodine absorption efficiencies of 99.99 percent have been obtained.[1395] However, organic iodides, such as methyl iodide are not effectively absorbed. To remove organic iodides the activated-charcoal beds should be preceded by a catalytic oxidation step to completely oxidize all organic vapors in the gas stream. The addition of the oxidation step prior to the charcoal bed is effective for removing organic iodides, but the bed life may be limited to a few months or a residence time of a few seconds may be required which is not practical in a large gas flow system. The charcoal beds are quite effective for the removal of trace quantities of elemental iodine and their use should probably be limited to the final iodine removal step.

Option No.3-Impregnated Charcoal. Special impregnated charcoals have been developed for removing methyl iodide. The impregnated charcoals presently under consideration are: (1) iodized with one or more iodine-containing substances, to provide I-131, I-127 exchange capability; or (2) triethylinediamine - impregnated to effect removal by the utilization of the alkyl halide-organic amine reaction. Methyl iodine retention efficiencies greater than 99 percent have been obtained with both these impregnated charcoals.[0669] The removal efficiencies for the iodine-impregnated charcoal refer only to I-131. The performance of these impregnated charcoal beds is drastically reduced by poisoning due to impurities in the air stream.[1386] Iodine-impregnated charcoal and triethylinediamine-impregnated charcoal are satisfactory absorbents for organic iodides, such as methyl iodide, but an upstream filter system may be required to remove impurities in the air.

Option No.4-Silver Zeolite. Inorganic and organic forms of iodine are both effectively removed from the off-gas stream by silver zeolite. The silver zeolite has ideal properties of nonflammability, capability of iodine absorption up to 500 C, retention of absorbed iodine up to 1,000 C, and rapid reaction times. The zeolite is a synthetic zeolite absorber (Linde Molecular Sieve 13X) in which the normal sodium zeolite matrix has been converted to silver zeolite. The silver zeolite retention efficiency of elemental iodine and methyl iodide is greater than 99.8 percent at temperatures varying from room temperature to 500 C.[2291] The efficiency of the silver zeolite is adversely effected by long-term exposure to organic contaminants in the air stream. The zeolite life expectancy can be extended by preceding the zeolite with an oxidation step. This is economically desirable since the basic cost of silver zeolite is 3 to 10 times the cost of charcoal. Silver zeolite is the most efficient absorber of all airborne iodine species and is particularly applicable to the large gas flows encountered in nuclear fuel reprocessing plants.

Krypton and Xenon Recovery

Option No.1-Activated Charcoal. Krypton and xenon are retained by adsorption beds of activated charcoal. In this process the krypton and xenon are cooled by means of cold trays and are then passed through a constant temperature (25 C) charcoal column. These absorption beds are used to provide holdup time which is long compared to the half-life of the isotopes. This process is effective for the 5.3 day xenon-133 but not for 10.8 year krypton-85. For xenon-133 the gas could be held up in a charcoal bed for a period of 18 days to reduce its activity 10 times or a period of 54 days for a reduction of a 1,000 times.

Option No.2-Cryogenic Distillation. A cryogenic distillation process for the recovery of krypton and xenon from off-gas streams generated during the reprocessing of nuclear reactor fuels has been applied at the Idaho Chemical Processing Plant.[2292] In this process the off-gas stream is first treated prior to entering the cryogenic system by passing the gas through a catalytic conversion system which removes nitrous oxide and hydrogen. In an off-gas stream with a high hydrogen content a special catalytic unit and condensor would also be required to reduce the hydrogen concentration in the off-gas to levels below the explosive limit. The off-gas is then fed to the cryogenic system which is cooled by liquid nitrogen. This system consists primarily of two regenerators, a distillation unit, and a batch still. The gas stream is cooled to -260 F in the two regenerators prior to entering the distillation column. In the distillation column, krypton and xenon are condensed and absorbed by liquid nitrogen which flows through the plates in the column. The krypton and xenon are dissolved in the liquid nitrogen and are transferred to a batch still where they are separated and purified in a fractionation step. This process has been applied in actual plant operation at the Idaho Chemical Processing Plant and is capable of processing up to 20 scfm of off-gas. The process has the potential for recovering 99 percent of the gases with 4 to 10 percent of nitrogen and oxygen impurities in the final product. Actual overall krypton-xenon recovery efficiencies have varied from 30 to 60 percent. The low recovery efficiencies were due to difficulties in operation of the gas cleanup step and to leaks within the product bottling system.

Option No.3-Fluorocarbon Solvents. Krypton and xenon can be effectively removed from contaminated air streams by selective absorption in fluorocarbon solvents, such as refrigerant-12 (dichlorodifluoromethane). This process has been tested on a pilot plant scale at processing rates up to 20 scfm of gas by Union Carbide at their Oak Ridge, Tennessee, facility.[1397] In this process, the removal of krypton and xenon is accomplished by contacting the gas stream with a stream of fluorocarbon solvent (refrigerant-11 or -12) in a packed absorber column at low temperatures (-177 to -21 F) and high pressure (169 to 437 psia). Besides krypton and xenon substantial amounts of oxygen, nitrogen, and argon are dissolved in the solvent. Since krypton and xenon are substantially more soluble in the solvent than these other gases, the absorber column is followed by a fractionator system where most of the dissolved nitrogen, argon, and oxygen is driven off. The solvent is then driven to a stripper system where the product gas concentrated in krypton and xenon is evolved and the solvent is recycled back to the absorber. Based on the pilot plant test data, a plant operating with an absorber at -30 F and 425 psia should give a krypton and xenon removal efficiency of over 99.7 percent with refrigerant-12 as the solvent.[1397] For application to fuel reprocessing plants with feed rates in excess of 100 scfm some scale-up of the pilot plant facility is required. This method offers the best potential for the effective removal of krypton and xenon from off-gas streams. It has been successfully operated on a pilot-plant scale but has not yet been applied in actual plant operations.

Disposal

Option No.1-Land Burial. Land burial of iodine, krypton, and xenon wastes, in small concentrations, at approved sites that are acceptable from a geologic and hydrologic standpoint, is an acceptable means of disposal. Their concentrations should not be in excess of 10^4 times their maximum permissible concentrations for the general population in 10CFR20.[2149] The burial trenches should be designed not to intercept the ground water table and constructed with a bottom drain and sump for water monitoring. The trenches should be covered with either asphalt or vegetation to prevent infiltration of water. The burial site design, geology, and hydrology should be in conformance with the criteria used in selecting and licensing the present commercial burial sites.[1423] Since land burial has successfully been practiced on a commercial scale, it should be considered as the most satisfactory method of disposing of low concentrations of these wastes.

Option No.2-Near Surface Storage. The disposal of high concentrations of these wastes in engineered surface facilities offers the best immediate method for disposal of these wastes. The technology for these facilities has been developed and the wastes will be under surveillance and control and can be retrieved, should this be required. The wastes will be stored in steel vaults encased in concrete. The vaults will be either air or water cooled. The periodic replacement of the waste containers will not be required for the short-lived isotopes, iodine-131 and xenon-133, but will probably be required for krypton-85 and iodine-129.

Option No.3-Salt Deposits. This method offers the greatest potential for the disposal of these radionuclides. This method of disposal has been under study by the Oak Ridge National Laboratory since 1957, and in November of 1970 a committee of the National Academy of Sciences recommended that the use of bedded salt for the disposal of radioactive wastes is satisfactory.[0733] The wastes are buried in rooms carved in the salt deposits approximately 1,000 ft below the ground. The salt is a good heat transmitter, provides about the same radioactive shielding as concrete, and can heal its own fractures by plastic flow. The critical problem is the selection of a site that meets the necessary design and geological criteria. For iodine-131 and xenon-133 wastes the life of the mine is not critical, but for krypton-85 wastes the life of the mine should extend beyond a few hundred years and for iodine-129 beyond several million years. Salt deposits should be considered for the disposal of these wastes at approved sites that are acceptable from a design and geological standpoint. In addition, a method of waste retrieval is required in the event the integrity of the site is destroyed.

To summarize, krypton, xenon, and iodine are released in the off-gas streams during reprocessing of the nuclear fuels. The iodine can be removed from the off-gas stream by silver zeolite. Krypton and xenon can be effectively removed by cryogenic distillation or by selective absorption in fluorcarbon solvents. Following recovery the wastes can be held to allow the short-lived isotopes such as iodine-131 and xenon-133 to decay. For iodine-131 and xenon-133 their activity is reduced by a factor of 10,000 in 106 days and 71 days, respectively. The long-lived isotopes krypton-85 (10.8 years) and iodine-129 (17 million years) should be encapsulated and disposed of in salt deposits or near-surface engineered facilities. The wastes to be disposed of can be encapsulated in high-pressure cylinders or solidified. A method for solidifying the gases xenon and krypton includes dispersion in glasses or resins and entrapment in molecular sieves or small pressurized steel bulbs which are in turn encased in epoxy resin.

6. APPLICABILITY TO NATIONAL DISPOSAL SITES

Iodine, xenon, and krypton are candidates for a National Disposal Site due to their projected growth with that of the civilian nuclear power program. The applicability of recovery processes to a National Disposal Site are dependent upon whether the reactor-produced wastes are reprocessed at the disposal site or are reprocessed elsewhere and shipped to the site. If reprocessed elsewhere, the wastes should be held up to six months to allow the short-lived isotopes, iodine-131 and xenon-131, to decay.

The recommended treatment for the recovery of iodine-129 and iodine-131 from reprocessing plant off-gas streams is by the use of silver zeolite. Krytpon-85 and xenon-133 can be removed by cryogenic distillation or absorption in fluorcarbon solvents. The recommended process for the disposal of these wastes are:

Process	Order of Preference	Remarks
Near-surface solid storage	First Choice	Demonstrated technology;waste under constant surveillance and control and can be retrieved.
Salt beds	Second Choice	Affords permanent disposal without constant surveillance; further development required for a waste retrievel plan and location of an acceptable site.

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HAZARDOUS WASTES PROPERTIES
WORKSHEET

Name Iodine-129

Half-life 1.7×10^{7} years

Type of Decay Negative Beta

Molecular Wt. 129 Melting Pt. 114 C Boiling Pt. 184 C

Density Gas: 11.27 grams/liter
Solid: 4.93 gm/cc at 20 C

Specific Power 7.08×10^{-8} watts/gm

Specific Activity 1.62×10^{-4} curies/gm

Structural Formula

$_{53}I^{129}$

Solubility

Cold Water Slightly soluble Hot Water Slightly soluble

Others: Dissolves readily in chloroform, carbon tetrachloride, & carbon disulfide

Decay Chain

$$\underset{(1.7\times10^{7}y)}{I^{129}} \longrightarrow \underset{(\text{Stable})}{Xe^{129}}$$

Radiation Energy Level & Intensities

Beta: 0.150 mev (100%)
Gamma: 0.038 mev (100%)

Shipping Regulations Classified as a transport group III radionuclide by the Department of Transportation

Comments

References: (1) 0766
(2) 2150

HAZARDOUS WASTES PROPERTIES WORKSHEET

Name Iodine-131

Structural Formula $_{53}I^{131}$

Half-life 8 days

Type of Decay Negative Beta

Molecular Wt. 131 Melting Pt. 114 C Boiling Pt. 1840 C

Density Gas: 11.27 gm/liter
Solid: 4.93 gm/cc at 20 C

Specific Power -

Specific Activity 1,230 curies/gm

Solubility

Cold Water Slightly soluble Hot Water Slightly soluble

Others: Dissolves readily in chloroform, carbon tetrachloride,& carbon disulfide

Decay Chain

I^{131} (8d) ———— Xe^{131} (stable)

Radiation Energy Level & Intensities

Beta:	0.810 Mev (0.7%)
	0.608 Mev (82.7%)
	0.330 Mev (9.3%)
	0.250 Mev (2.8%)
Gamma:	0.723 Mev (1.6%)
	0.637 Mev (6.8%)
	0.364 Mev (82%)
	0.284 Mev (5.4%)
	0.080 Mev (2.6%)

Shipping Regulations Classified as a transport group III radionuclide by the Department of Transportation

Comments

References: (1) 0766
(2) 2150

HAZARDOUS WASTES PROPERTIES WORKSHEET

Name Krypton-85

Half-life 10.8 years

Type of Decay Negative Beta

Molecular Wt. 85 Melting Pt. -157 C Boiling Pt. -152 C

Density Gas: 3.733 gm/liter @ 0 C
Liquid: 2.16 gm/cc @ -153 C

Specific Power 0.53 watts/gm

Specific Activity 397 curies/gm

Structural Formula

$_{36}Kr^{85}$

Solubility

Cold Water

Hot Water

Others: Chemically inert

Decay Chain

$$Kr^{85} \xrightarrow{B^{-1}} Rb^{85}$$

(10.8y) (stable)

Radiation Energy Level & Intensities

Beta: 0.690 Mev (99.4%)
0.150 Mev (0.6%)

Gamma: 0.514 Mev (0.4%)

Shipping Regulations Classified as a transport group VI radionuclide at pressure less than 14.7 psia & as a group III radionuclide at pressures greater than 14.7 psia by the Department of Transportation.

Comments Krypton is a member of the so-called rare or inert gases.

References: (1) 0766
(2) 2150

HAZARDOUS WASTES PROPERTIES WORKSHEET

Name Xenon-133

Half-life 5.3 days

Type of Decay Negative Beta

Structural Formula

$_{54}Xe^{133}$

Molecular Wt. 133 Melting Pt. -112 C Boiling Pt. -107 C

Specific Power

Specific Activity $1.86x10^{5}$ curies/gm

Solubility

Cold Water Hot Water

Others: Chemically inert

Density

Gas: 5.495 gm/liter at 20 C
Liquid: 3.52 gm/cc at -107C
Solid: 2.70 gm/cc at

Decay Chain

$$\underset{(5.3\text{ days})}{Xe^{133}} \xrightarrow{B^{-1}} \underset{(\text{stable})}{Cs^{133}}$$

Radiation Energy Level & Intensities

Beta: 0.346 Mev (100%)

Gamma: 0.809 Mev (100%)

Shipping Regulations Classified as a transport group VI radionuclide at pressures less than 14.7 psia & as a group III radionuclide at pressures greater than 14.7 psia by the Department of Transportation

Comments Xenon is a member of the so-called rare or inert gases

References: (1) 0766
(2) 2150

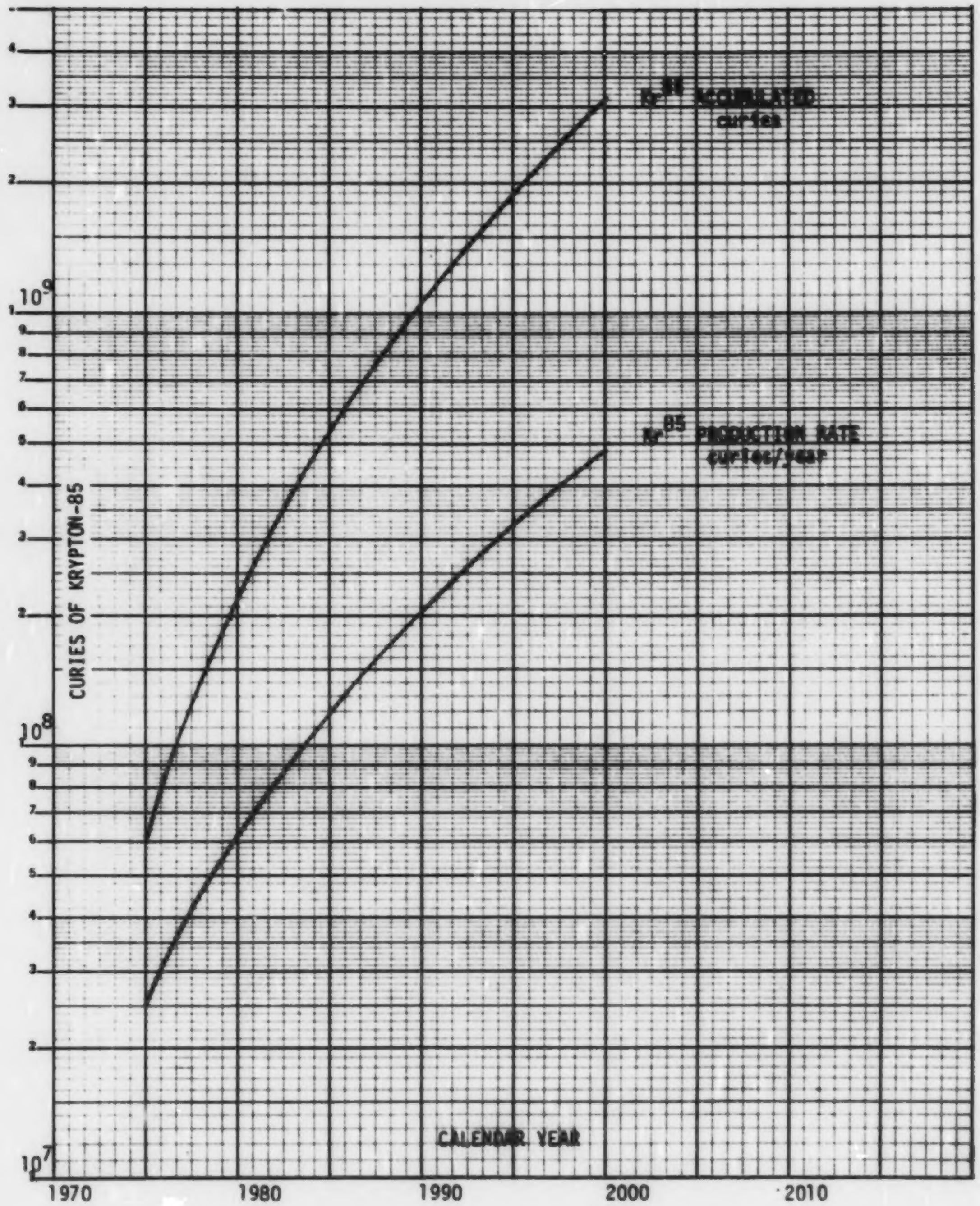

Figure 1. Estimated Production of Krypton-85 from the Nuclear Power Industry. (0705)

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TABLE 1

THERMAL-NEUTRON FISSION YIELD OF KRYPTON AND XENON FROM U-235 REACTOR FUELS

Fission Products	Fission Yield Percent	Half-Life
Krypton-83	0.544	Stable
Krypton-84	1.00	Stable
Krypton-85	1.293	10.76 years
Krypton-86	2.02	Stable
Xenon-131	2.93	Stable
Xenon-132	4.38	Stable
Xenon-133	6.62	5.3 days
Xenon-134	8.06	Stable
Xenon-135	6.30	9.2 hours
Xenon-136	6.46	Stable

TABLE 2

ANNUAL PRODUCTION OF IODINE-129 FROM THE CIVILIAN NUCLEAR POWER PROGRAM [705]

Light-Water Reactor Fuels

Annual Production	1970	1980	Calendar Year 1985	1990	2000	2020
grams/year	$.012x10^6$	$.69x10^6$	$1.24x10^6$	$1.4x10^6$	$1.11x10^6$	$3.26x10^6$
curies/year	1.97	112	202	229	182	534
watts/year	.0085	.0485	.0874	.099	.078	.231

Fast-Breeder Reactor Fuels

Annual Production	1970	1980	Calendar Year 1985	1990	2000	2020
grams/year			$.116x10^6$	$.70x10^6$	$3.0x10^6$	$9.0x10^6$
curies/year			19.4	117	500	1500
watts/year			.0083	.051	.215	.649

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TABLE 3

IODINE, KRYPTON, AND XENON DOSE TO A PARTICULAR BODY ORGAN FOLLOWING INHALATION OF ONE MICROCURIE OF THE NUCLIDE

Isotone	Form	Organ	Dose rem
Iodine-129	Insoluble	Lung	0.09
Iodine-129	Soluble	Thyroid	7.0
Iodine-131	Insolbule	Lung	0.03
Iodine-131	Soluble	Thyroid	1.6
Krypton-85	Insoluble	Lung	0.26
Xenon-133	Insoluble	Lung	0.02

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TABLE 4

IODINE, KRYPTON, AND XENON ENVIRONMENTAL RELEASE RATES 2149

Radionuclide	Form	Concentration in Air (microcuries/milliliter)	Concentration in Water (microcuries/milliliter)
Iodine-129	Soluble	2×10^{-11}	6×10^{-8}
Iodine-129	Insoluble	2×10^{-9}	2×10^{-4}
Iodine-131	Soluble	1×10^{-10}	3×10^{-7}
Iodine-131	Insoluble	1×10^{-8}	6×10^{-5}
Krypton-85	Submersion*	3×10^{-7}	---
Xenon-133	Submersion*	3×10^{-7}	---

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*Submersion means that the values given are for submersion in a semispherical infinite cloud of airborne material.

APPENDIX C - WASTE QUANTITIES AND LOCATIONS

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ESTIMATED PESTICIDE WASTE GENERATION

Summarized in the following tables are estimates of pesticide waste generation throughout the United States. The data is generally presented in terms of USDA Regions (Table 1) as well as individual states when possible. For purposes of this report, the broad term pesticides was divided into three types; herbicides, insecticides and fungicides. Each of these three types of pesticide was further divided into chemcial categories (Table 2). Three kinds of pesticide wastes are considered: pesticide production wastes, agricultural wastes, and Department of Defense wastes. In each case, the data is tabulated (Tables 3, 4, 5, 6, 7, 8 and 9) and the assumptions that were made are footnoted on the appropriate table.

The physical form of each pesticide waste expected to appear at disposal sites will depend on the waste source. Pesticide production wastes are generally in the form of organic sludges, tars, off-grade products, and dilute liquids. It is not expected that dilute liquid pesticide wastes will be treated at disposal sites. The pesticide waste estimations presented in Table 7 are total waste estimates (both dilute and concentrated waste forms). The ratio of dilute waste to concentrated waste (sludge and tars and off-grade products) usually ranges from .01 to 100 for the spectrum of chemical production processes utilized in the pesticide industry.[2290] Since this ratio is extremely sensitive to the particular process used, no effort was made to further qualify the production waste estimates. Agricultural and Department of Defense wastes (Tables 8 and 9) are in the form of relatively pure materials.

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2277. Johnson, O. Pesticides' 72- part 1. Chemical Week 110(25):33-66, June 21, 1972.

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TABLE 1. USDA REGIONS

Region 1, North-Eastern
- New Hampshire
- Maine
- Vermont
- New York
- New Jersey
- Pennsylvania
- Delaware
- Maryland
- Massachusetts
- Rhode Island
- Connecticut

Region 2, Appalachian
- Virginia
- West Virginia
- North Carolina
- Kentucky
- Tennessee

Region 3, South-Eastern
- South Carolina
- Georgia
- Florida
- Alabama

Region 4, Delta States
- Mississippi
- Arkansas
- Louisiana

Region 5, Corn Belt
- Ohio
- Indiana
- Illinois
- Iowa
- Missouri

Region 6, Lake States
- Michigan
- Wisconsin
- Minnesota

Region 7, Northern Plains
- North Dakota
- South Dakota
- Nebraska
- Kansas

Region 8, Southern Plains
- Oklahoma
- Texas

Region 9, Mountain States
- Montana
- Idaho
- Wyoming
- Colorado
- New Mexico
- Arizona
- Utah
- Nevada

Region 10, Pacific States
- Washington
- Oregon
- California
- Alaska*
- Hawaii*

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[*] Although Alaska and Hawaii are in Region 10, they were not included in the pesticide waste estimates which refer to USDA regions.

TABLE 2. REPRESENTATIVE PESTICIDE TYPES AND CATEGORIES

HERBICIDES	CATEGORY
Dacthal	Benzoic
Silvex	Benzoic
Amitol	Triazine
Diuron	Phenyl-urea
Fenuron	Phenyl-urea
Monuron	Phenyl-urea
2-4D	Phenoxy
2-4-5T	Phenoxy
3-3-4D	Phenoxy
Dinitrocresol	Dinitro
Diquat	Other Ogranic
Bromocil	Other Organic
Arcadian	Other Organic
Dowpon 2-2D	Chlorinated Aliphatic

INSECTICES	CATEGORY
DDT	Polychlorinated Hydrocarbon
Chlordane	Polychlorinated Hydrocarbon
Dieldrin	Polychlorinated Hydrocarbon
Lindane	Polychlorinated Hydrocarbon
Dichlorobenil	Polychlorinated Hydrocarbon
DDD	Polychlorinated Hydrocarbon
Aldrin	Polychlorinated Hydrocarbon
Endrin	Polychlorinated Hydrocarbon
Heptachlor	Polychlorinated Hydrocarbon
Benzene Hexachloride	Polychlorinated Hydrocarbon
Malathion	Organophosphorus
Methyl Parathion	Organophosphorus
Parathion	Organophosphorus
Demeton	Organophosphorus
Guthion	Organophosphorus
Ethylene Bromide	Other Organic
Methyl Bromide	Other Organic
Methyl Chloride	Other Organic
Fumarin	Other Organic
Bagon	Other Organic
Pyrethrin	Other Organic

FUNGACIDES	CATEGORY
Thiram	Organic
Zineb	Organic

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TABLE 3. PESTICIDE PRODUCTION PLANT LOCATIONS IN 1969[0449]

USDA Region & State	No. of Plant Sites
Region 1, North-Eastern	
New Hampshire	0
Maine	0
Vermont	0
New York	12
New Jersey	15
Pennsylvania	8
Delaware	0
Maryland	3
Massachusetts	7
Rhode Island	0
Connecticut	1
Region 2, Appalachina	
Virginia	5
West Virginia	1
North Carolina	16
Kentucky	1
Tennessee	3
Region 3, South-Eastern	
South Carolina	5
Georgia	18
Florida	18
Alabama	12
Region 4, Delta States	
Mississippi	9
Arkansas	5
Louisiana	7
Region 5, Corn Belt	
Ohio	10
Indiana	1
Illinois	15
Iowa	7
Missouri	9
Region 6, Lake States	
Michigan	7
Wisconsin	7
Minnesota	5
Region 7, Northern Plains	
North Dakota	0
South Dakota	0
Nebraska	4
Kansas	4
Region 8, Southern Plains	
Oklahoma	3
Texas	34
Region 9, Mountain States	
Montana	0
Idaho	1
Wyoming	0
Colorado	7
New Mexico	0
Arizona	11
Utah	0
Nevada	1
Region 10, Pacific States*	
Washington	8
Oregon	4
California	56

Total U.S. Plant Sites = 340

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* Although Alaska and Hawaii are in Region 10, they were not included in the pesticide waste estimates.

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TABLE 4. ESTIMATED MAJOR U.S. HERBICIDE PRODUCTION IN 1971[2276,2277]

UNITS IN MILLION POUNDS

Benzoic	
Amiben	20
Banvel	2
Betasan	<1
Dacthal	2
Lasso	20
Naptalam	2
PCB and Salts	46
Picloram	3
Propanil	6
Ramrod	23
Silvex	3
2,3,6-TBA	2
Total	~130

Triazine	
Amitrole	1
Aatrex	90
Princep	5
Propazine	4
Total	~100

Phenyl-urea	
Chlorobenzilate	2
Chloroxuron	<1
Diuron	6
Monuron	<1
Siduron	<1
Linuron	2
Total	~13

Phenoxy	
2,4-D	45
2,4,5T	6
Total	~51

Dinitro	
Benefin	1
Dinoseb	3
Planavin	2
Trifluralin	25
Total	~31

Chlorinated Aliphatic	
Dalapon	5
Randox	10
TCA	1
Total	16

Organic Arsenical	
DSMA-MSMA	35
Total	35

Carbonate	
Avadex	<1
Avadex BW	<1
Azak	<1
Barban	<1
Eptam	5
Ro-Neet	<1
Sutan	6
Tillam	1
Vegadex	<1
Vernam	2
Total	~20

Other Organic	
Aqualin	<1
Bromasil	8
Cacodvlic Acid	2
Chloropropharm	2
Def	5
Endothall	2
Fluometuron	4
Fluorodifen	1
Folex	3
Herban	2
Maleic hydrazide	3
Ordam	<1
Terbacil	<1
Total	~35

Total major herbicide production = ~431 million pounds in 1971.

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TABLE 5. ESTIMATED MAJOR U.S. INSECTICIDE PRODUCTION IN 1971[2276,2277]

UNITS IN MILLION POUNDS

Polychlorinated Hydrocarbon	
Acaralate	<1
Aldrin	10
Chlordane	25
Dicofol	4
Dieldrin	<1
DDT	45
Endosulfan	2
Endrin	<1
Heptachlor	6
Lindane	<1
Methoxychlor	10
Mirex	<1
Para-dichlorobenzene	60
Toxaphen	50
Total	~217

Organophosphorus	
Abate	<1
Aspon	<1
Azodrin	5
Bidrin	<1
Co Ral	<1
Dasanit	4
Diazinon	10
Dichlorvos	<1
Dimethoate	2
Dioxathion	<1
Disulfoton	8
Dursban	5
Dyfonate	2
Ethion	2
Fenthion	<1
Guthion	4
Malathion	30
Meta-Systox R	<1
Methyl parathion	45
Mevinphos	<1
Mocap	<1
Naled	2
Parathion	15
Phosphamidon	<1
Ronnel	2
Ruelene	2
TEPP	<1
Trithion	2
Zinophos	<1
Total	~153

Carbamate	
Bux Ten	6
Carbaryl	55
Carbofuran	8
Total	69

Other Organic	
DBCP	10
Deet	<1
Diphacin	<1
Ethyl hexanediol	<1
Methomyl	2
Methyl bromide	22
MGK 264	<1
MGK 326	<1
Nicotine	<1
Pyrethrins	<1
Rotenone	<1
Temik	2
Trooital	<1
Warfarin	12
Total	~57

Total major insecticide production = ~496 million pounds in 1971.

TABLE 6. MAJOR U.S. ORGANIC FUNGICIDE PRODUCTION IN 1971[2276,2277]
UNITS IN MILLION POUNDS

Organic Fungicide	
Benomyl	<1
Captan	18
Chloroneb	<1
Cyprex	2
DCNA	<1
Difolatan	2
Diphenamic	3
Folpet	2
Karathane	<1
PCNB	3
Total	~34

Total major fungicide production = ~34 million pounds in 1971.

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TABLE 7. ESTIMATED* PESTICIDE PRODUCTION AND ASSOCIATED PRODUCTION WASTE BY USDA REGION AND STATE0049,2276,2277

UNITS, 100 LB/YEAR

USDA Region and State	Herbicide Production	Insecticide Production	Fungicide Production	Herbicide Waste	Insecticide Waste	Fungicide Waste
Region 1, North-Eastern						
New Hampshire	-	-	-	-	-	-
Maine	-	-	-	-	-	-
Vermont	-	-	-	-	-	-
New York	15,200	17,500	1,200	46	53	3.6
New Jersey	19,000	21,900	1,500	57	67	4.5
Pennsylvania	10,100	11,700	800	30	35	2.4
Delaware	-	-	-	-	-	-
Maryland	3,800	4,400	300	11	13	.9
Massachusetts	8,900	10,200	700	27	31	2.1
Rhode Island	-	-	-	-	-	-
Connecticut	1,300	1,500	100	3.9	4.5	.3
Region 2, Appalachian						
Virginia	6,300	7,300	500	19	22	1.5
West Virginia	1,300	1,500	100	3.9	4.5	.3
North Carolina	20,300	23,300	1,600	61	70	4.8
Kentucky	1,300	1,500	100	3.9	4.5	.3
Tennessee	3,800	4,400	300	11	13	.9
Region 3, South-Eastern						
South Carolina	6,300	7,300	500	19	22	1.5
Georgia	22,800	26,200	1,800	68	77	5.4
Florida	22,800	26,200	1,800	68	77	5.4
Alabama	15,200	17,500	1,200	46	53	3.6
Region 4, Delta States						
Mississippi	11,400	13,100	900	34	39	2.7
Arkansas	6,300	7,300	500	19	22	1.5
Louisiana	8,900	10,200	700	27	31	2.1
Region 5, Corn Belt						
Ohio	12,700	14,600	1,000	38	44	3.0
Indiana	1,300	1,500	100	3.9	4.5	.3
Illinois	19,000	21,900	1,500	57	66	4.5
Iowa	8,900	10,200	700	27	31	2.1
Missouri	11,400	13,100	900	34	39	2.7
Region 6, Lake States						
Michigan	8,900	10,200	700	27	31	2.1
Wisconsin	8,900	10,200	700	27	31	2.1
Minnesota	6,300	7,300	[illegible]	[illegible]	72	1.5
Region 7, Northern Plains						
North Dakota	-	-	-	-	-	-
South Dakota	-	-	-	-	-	-
Nebraska	5,100	5,800	400	15	17	1.2
Kansas	5,100	5,800	400	15	17	1.2
Region 8, Southern Plains						
Oklahoma	3,800	4,700	300	11	14	.9
Texas	43,100	45,600	3,400	129	137	10.
Region 9, Mountain States						
Montana	-	-	-	-	-	-
Idaho	1,300	1,500	100	3.9	4.5	.3
Wyoming	-	-	-	-	-	-
Colorado	8,900	10,200	700	27	31	2.1
New Mexico	-	-	-	-	-	-
Arizona	13,900	16,000	1,100	42	48	3.3
Utah	-	-	-	-	-	-
Nevada	1,300	1,500	100	3.9	4.5	.3
Region 10, Pacific States						
Washington	10,100	11,700	800	30	35	2.4
Oregon	5,100	5,800	400	15	17	1.2
California	71,000	81,700	5,600	213	245	17.

* These estimations are based on the following assumptions:

(1) Current operational plant sites are those presented in Table 3.

(2) All plant production rates are equal.

(3) An equal herbicide to insecticide to fungicide ratio in all production states.

(4) Total herbicide, insecticide and fungicide production rates are those presented in Tables 4, 5, and 6.

(5) An average pesticide production waste factor of 3 pounds of waste per 1000 pounds of product.

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TABLE 8. AGRICULTURAL PESTICIDE WASTE SURVEY*

UNITS LB/YR

Pesticide Type and Category	USDA REGION 1	2	3	4	5	6	7	8	9	10	Total
Herbicides											
Benzoic	-	-	100	300	11500	1600	1100	-	150	2800	17550
Triazine	9000	7400	800	200	19600	18300	4500	700	100	700	61300
Phenyl-urea	1000	800	1000	4000	1000	300	10	400	30	900	9440
Phenoxy	6400	6000	5600	5300	35500	16300	41700	12100	25400	26400	180700
Dinitro	8800	1200	4000	-	400	300	-	50	100	2900	17750
Chlorinated Aliphatic	4000	-	-	1100	800	3000	1400	100	-	100	10500
Organic Arsenical	-	40	60	4200	-	-	-	1200	-	-	5500
Carbamate	40	800	1100	5400	19000	2500	1000	16000	1000	3000	49800
Other Organic	200	2400	2400	1800	5700	900	100	600	200	500	14800
Insecticides											
Polychlorinated Hydrocarbons	4000	24700	70500	48700	4300	30200	1600	30600	5600	10200	230400
Organophosphorus	3400	3900	10900	15000	1400	4400	5400	13700	3800	16300	78200
Other Organic	6000	3400	8000	5800	2200	1500	100	6000	700	6900	40600
Fungicides											
Organic	3900	10100	35600	100	3800	2100	150	2900	600	21500	80750
Total Pesticides	46740	60740	140060	91900	133400	55200	57060	84350	37680	92200	797290

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*Recoverable agricultural waste is assumed to be in the form of container residues only.
Estimatation methods are based on those of Jansen[0619] and reflect 1970 data obtained from Pesticide Review.[1738]
Residue factors used were obtained from a U. C. Davis study: 400 gm/55-gal container
40 gm/ 5-gal container
14 gm/ 1-gal container

TABLE 9. DEPARTMENT OF DEFENSE WASTE PESTICIDE SURVEY[a]

UNITS, LB TOTAL - LB ACTIVE INGREDIENT

USDA REGION AND STATE[b]	HERBICIDES						INSECTICIDES			FUNGICIDES	Approximate Total Pesticides
	Benzoic	Phenyl-Urea	Phenoxy	Chlorinated Aliphatic	Carbamate	Other Organic	Polychlorinated Hydrocarbons	Organo-Phosphorus	Other Organic	Organic	
Region 1											
North-Eastern											
New York	150 - 450						90,000 - 8,200	100 - 50		150-130	90,000- 9,000
New Jersey							1,100 - 800				1,100- 800
Pennsylvania		1,100 - 900	1,200 - 1,100				32,700 - 30,200				35,000-32,000
New Hampshire							430 - 100				400- 100
Maryland				953 - 850			1,550 - 1,550				1,700- 1,600
Massachusetts			80 - 80				700 - 50				800- 150
Washington D.C.							4,800 - 1,100				4,800- 1,100
Region 2											
Appalachian											
Virginia	350 - 280	120 - 100	1,200 - 1,000	300 - 260			98,700 - 35,100	1,900- 500			92,900-37,300
North Carolina							55,300 - 13,200		750- 750		56,000-14,000
Tennessee							39,000 - 15,300				39,000-15,300
Region 3											
South-Eastern											
South Carolina							120 - 20				120- 20
Georgia	,200 - 1,200	700 - 700	4,500 - 4,500	3,100 - 2,800		2,000 - 2,000	69,400 - 11,300	4,500-4,300	7,400- 7,300		92,000-33,400
Florida			2,000 - 1,600	50 - 40		5,000 - 2,500	58,500 - 20,100				65,500-24,200
Alabama							1,900 - 1,400	25- 1			1,900- 1,400
Region 4											
Delta States											
Mississippi			6,854,000 - 6,815,000				5,100 - 1,100				6,959,000-6,816,000
Arkansas		120 - 120									120- 120
Region 5											
Corn Belt											
Ohio							2,600 - 160				2,600- 160
Indiana	75 - 20		570 - 570	130 - 110	200 - 120		300 - 80	840- 380	350- 350		2,500- 1,600
Illinois			5,000 - 5,000				19,800 - 3,800				25,400- 8,800
Missouri							1,900 - 1,800	500- 80			2,400- 1,900
Region 6											
Lake States											
Michigan							1,600 - 850				1,600- 850
Region 7											
Northern Plains											
South Dakota						50 - 1	2,000 - 100		60- 60		2,100- 160
Nebraska							70 - 10				70- 10
Kansas							60 - 30				60- 30
Region 8											
Southern Plains											
Oklahoma							210 - 20				210- 20
Texas			1,222,000 - 1,16[illegible],000	50 - 40			44,600 - 7,300				1,267,000-1,168,000
Region 9											
Mountain States											
Wyoming							160 - 30	250- 130			410- 220
Colorado					120 -		12,400 - 3,300	500- 10			13,000- 3,400
New Mexico	60 - 50		1,600 - 1,600	75 - 60			170 - 80				1,900- 1,800
Arizona	600 - 500		50 - 40				2,800 - 700				3,400- 1,200
Utah				200 - 200			7,200 - 1,600	1,250- 660			8,700- 2,500
Region 10											
Pacific States											
Washington							37,300 - 3,100	10-5			37,300- 3,100
Oregon							353,500 - 30,800		20,000-20,000		373,500-50,800
California						1,200 - 10	377,600 - 65,500	30,100-25,000	200- 2		369,100-90,500
Alaska			2,900 - 2,900				15,500 - 10,300	90,000-73,000			116,400-86,200
Hawaii							18,800 - 1,100				18,800- 1,100

(a) Basic data obtained from Department of Defense inventory - pesticide wastes.[2222]
Liquid pesticide density assumed equal to water density.
When no active ingredient concentration data available, 100 percent assumed.

(b) States not listed in appropriate USDA regions contain no DOD pesticide wastes.

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ESTIMATED CADMIUM WASTE GENERATION

Summarized in the following tables are estimates of soluble cadmium wastes generated by the electroplating industry in the United States (Table 2). The data is generally presented in terms of U.S. Bureau of Census Regions (Table 1) as well as individual states.

The electroplating industry is the major source of soluble cadmium waste. Other sources of aqueous cadmium waste may be cadmium compound manufacturers, the paint industry (pigments), and the plastic industry. Mr. Bechemeyer of the Chemetron Corporation claims that the manufacturers of cadmium compounds recover most of their waste cadmium and are not a major source of cadmium pollution.[2282] The pigment and plastic industries use cadmium compounds in their processes, but are not considered to be large sources of cadmium waste.[2283, 2284, 2286]

The total amount of cadmium waste generated in the United States was estimated by assuming that 18 percent of all the cadmium used for electroplating is lost as waste. The 18 percent figure was supplied by Leslie E. Lancy of Lancy Laboratories who has had many years of experience in dealing with electroplating waste problems.[2287] Since approximately 8,000,000 lb of cadmium are used in the United States each year for electroplating (this figure represents the amount of cadmium oxide and other soluble cadmium compounds used to make up the plating bath and the amount of cadmium metal used in the plating electrodes), 18 percent of this number gives 1.44 million lb of water soluble cadmium waste generated per year by the electroplating industry.

The 1.44 million lb of cadmium waste were distributed geographically by applying a waste generation factor to each state. These factors were estimated by using "value added" dollar amounts for finished metal products produced in each major city in the United States. The value added data was supplied by the U.S. Census Bureau.

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Cadmium waste from the electroplating industry is in the form of a dilute aqueous solution (200-300 ppm of dissolved solids) composed of other heavy metals, cyanides, and metal surface cleaning agents (acid solvents and alkali phosphates).[2285]

Cadmium electroplating wastes are generally treated by coagulation with commercial grade lime, followed by sedimentation and sand filtration. Activated-carbon beds and ion exchange units are also successful methods for treating aqueous cadmium wastes.

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2285. Personal communication. Harold McVea, Udylite Corporation, to D. Dal Porto, TRW Systems, Aug. 18, 1972. Cadmium waste production.

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2287. Personal communication. Leslie Lancy, Lancy Laboratories, to D. Dal Porto, TRW Systems, Aug. 21, 1972. Cadmium waste production.

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TABLE 1. U.S. BUREAU OF CENSUS REGIONS

Region 1

Maine
Vermont
New Hampshire
Massachusetts
Rhode Island
Connecticut

Region 2

New York
Pennsylvania
New Jersey

Region 3

Wisconsin
Illinois
Indiana
Ohio
Michigan

Region 4

North Dakota
South Dakota
Minnesota
Iowa
Nebraska
Kansas
Missouri

Region 5

Delaware
Maryland
Washington, D.C.
West Virginia
North Carolina
South Carolina
Florida

Region 6

Kentucky
Tennessee
Mississippi
Alabama

Region 7

Texas
Oklahoma
Arkansas
Louisiana

Region 8

Montana
Idaho
Wyoming
Nevada
Utah
Colorado
Arizona
New Mexico

Region 9

Washington
Oregon
California
Hawaii

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TABLE 2. CADMIUM WASTES GENERATED IN THE ELECTROPLATING INDUSTRY

U.S. Bureau of Census Region and State[a]	Quantity of Waste (in thousands of pounds per year)
Region 1	
Massachusetts	90.3
Rhode Island	13.2
Connecticut	84.5
Region 2	
New York	140.2
Pennsylvania	131.2
New Jersey	138.6
Region 3	
Wisconsin	25.0
Illinois	126.2
Indiana	18.0
Ohio	166.2
Michigan	128.2
Region 4	
Minnesota	21.0
Iowa	6.0
Nebraska	2.0
Kansas	14.0
Missouri	22.0
Region 5	
Delaware	4.0
Maryland	30.0
Washington D.C.	4.0
West Virginia	2.0
Virginia	4.0
North Carolina	4.0
South Carolina	1.0
Georgia	4.0
Florida	17.0

TABLE 2. CONTINUED

U.S. Bureau of Census Region and State[a]	Quantity of Waste (in thousands of pounds per year)
Region 6	
Kentucky	10.0
Tennessee	18.0
Mississippi	1.0
Alabama	4.0
Region 7	
Texas	37.0
Oklahoma	8.0
Arkansas	1.0
Louisiana	6.0
Region 8	
Utah	4.0
Colorado	4.0
Arizona	2.0
Region 9	
Washington	10.0
Oregon	10.0
California	128.2

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[a] States not listed in appropriate regions contain no cadmium wastes.

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ESTIMATED LEAD WASTE GENERATION

Summarized in the following table is the generation of wastes from two sources of lead compound contaminated waste. The first source is paint manufacture where lead compounds, primarily basic lead carbonate, are used for pigments. The estimate indicates both the total amount of paint waste (lower number) and the amount of lead as lead metal (upper number). The paint sludge estimate is 0.5 percent of paint manufactured left is vats and is distributed by Bureau of Census regions on the basis of manufacturers with over 20 employees. The old paint estimate assumes that 10 percent of all paint manufactured is discarded in the containers in which it is sold. The distribution of old paint is assumed to follow the distribution of population in the United States. The lead in brine sludge is an estimate from the Booz-Allen first contract Final Report.

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LEAD AND COMPOUNDS

Material	Total	I	II	III	IV	V	VI	VII	VIII	IX	Explanation	Source
	Annual Waste Production (#/yr)											
285 Paint Sludge	1.15×10^5	5.1×10^3	2.8×10^3	3.1×10^3	8.3×10^3	1.2×10^4	4.7×10^3	7.9×10^3	1.4×10^3	1.7×10^4	Industrial waste 5% in vats (Paint Industry Distribution)	
Basic Lead Carbonate	2×10^7	8.8×10^5	4.86×10^6	5.38×10^6	1.44×10^6	2.06×10^6	8.2×10^5	1.38×10^6	2.4×10^5	2.94×10^6		
Old Paint	2.3×10^6	1.3×10^5	4.3×10^5	4.6×10^5	1.8×10^5	3.4×10^5	1.4×10^5	2.2×10^5	9.4×10^4	3.0×10^5	Municipal waste 10% in cans (Population Distribution)	
	4×10^8	2.32×10^7	7.4×10^7	7.9×10^7	3.2×10^7	5.9×10^7	2.5×10^7	3.8×10^7	1.6×10^7	5.2×10^7		
2812 Brine Sludge	3.5×10^6	5×10^3	2.55×10^5	3.4×10^5	4×10^4	4.5×10^5	3.3×10^5	1.9×10^6	8×10^4	1.6×10^5		Booz-Allen

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ESTIMATED MERCURY WASTE GENERATION

Summarized in the following table is the generation mercury containing wastes. The first two sources are again paint manufacture and usage where organic mercury compounds are the active ingredient in anti-fouling and mildew-resistant paints. The same assumptions previously discussed for lead waste in paints were used. Mercury in brine sludge is discussed in the inorganic mercury Profile Report and its quantity was computed on the basis of 12 lb of mercury per ton of chlorine. The mercury fungicide wastes are computed on the basis of the pesticide distribution throughout the United States. The electrical apparatus estimate is based on population distributions and the assumption that 50 percent of the annual production of the mercury and mercury compound containing apparatus goes into the waste stream annually. Currently stored surplus or obsolete materials from the military inventory are also presented.

MERCURY AND COMPOUNDS

Material	Total	I	II	III	IV	V	VI	VII	VIII	IX	Explanation	Source
	Annual Waste Production (#/yr)											
285 Paint Sludge	3000 in 2×10^7	132 in 8.8×10^5	729 in 4.86×10^6	807 in 5.38×10^6	216 in 1.44×10^6	309 in 2.06×10^6	123 in 8.2×10^5	207 in 1.38×10^6	36 in 2.4×10^5	441 in 2.94×10^6	Industrial waste 0.5% left in vats Paint Industry Distribution	TRW est.
Old Paint	60000 in 4×10^8	3480 in 2.32×10^7	11160 in 7.44×10^7	11880 in 7.92×10^7	4800 in 3.2×10^7	8880 in 5.92×10^7	3780 in 2.52×10^7	5700 in 3.8×10^7	2460 in 1.64×10^7	7860 in 5.24×10^7	Municipal waste 10% left in cans Population Distribution	TRW est.
2812 Brine Sludge	3.9×10^5 32.4×10^6	8.4×10^3 6.97×10^5	4.6×10^4 3.8×10^6	3.24×10^4 2.7×10^6	0	7.2×10^4 6.0×10^6	9.1×10^4 7.6×10^6	9.8×10^4 8.2×10^6	0	4.1×10^4 3.41×10^6	Industrial waste Hg 0.12#/ton chlorine Total 10#/ton Chlorine Manufacturing Distribution	TRW est.
Mercury Fungicides in Containers	534		26		41		301	20	4	142	Fungicide distribution Distribution 0.66% Pesticide Distribution	TRW est.
Electrical Apparatus (Metal & Salts)	8.0×10^5	5.6×10^4	1.6×10^5	1.6×10^5	6.5×10^4	1.2×10^5	5.5×10^4	7.9×10^4	3.3×10^4	1.1×10^5	Municipal Solids Waste 10%/yr Population Distribution	TRW est.
	Stored Wastes #											
Mercuric Nitrate	5									5	Military Inventory	2222
Mercuric and Mercurous Chloride	210	100			110						Military Inventory	2222

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ESTIMATED ARSENIC WASTE GENERATION

Summarized in the following table are estimates of arsenic compound wastes generated by various industrial sources in the United States. The estimates are in terms of Bureau of Census regions.

The first category is an estimate of arsenic oxide currently released to the atmosphere in the burning of coal for power generation. While this is not an immediate waste disposal problem since it is not collected, it is expected that gas cleaning equipment added for the purpose of sulfur oxide removal and other air correction will require the disposal of an arsenic containing waste.

The second category is the arsenic oxide recovered as component of particulate from the refining of copper, lead and zinc ores. Much of the recovered particulate is currently sent to ASARCO for further refining and recovery of additional metal values. The lead arsenate and calcium arsenate estimates are based on pesticide usage and its distribution. The pesticide wastes are shown distributed by combinations of Bureau of Census regions which corresponds to appropriate combinations of the USDA regions. Large quantities of arsenic compounds and arsenic-contaminated materials are currently stored awaiting disposal. Soil contaminated by a manufacturer of arsenal chemical munitions are currently awaiting disposal at Rocky Mountain Arsenal. ASARCO currently has a large quantity of crude arsenic from its flue dust refining operations stored. The stored pesticides are part of the military inventory. The contaminated soil numbers are given in terms of percent because the total quantity is unknown. This soil has been contaminated by the continued use of arsenic containing pesticides. The distribution shown is the agricultural production distribution.

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ARSENIC AND COMPOUNDS

Material	Total	I	II	III	IV	V	VI	VII	VIII	IX	Explanation	Source
	Annual Waste Production (#/yr)											
As_2O_3 Airborne from Power Generation. (100% Recovery)	6×10^6	9.6×10^4	8.8×10^5	2.3×10^5	4.3×10^5	1.2×10^6	8.9×10^5		2.1×10^5		Coal Burning Power Plants 3000 tons/yr of As_2O_3 released Power Plant Distribution	
Copper, Lead & Zinc Refining Major Source (95% Recovery)	2.4×10^7		5.5×10^5	2.9×10^5	2.1×10^6	1×10^5	1.7×10^5	2.4×10^6	1.7×10^7	1.6×10^6	Combined Total (est) Refinery Distribution	
Lead Arsenate Pesticide Container	11800	590		1770		3824		4130	354	1062	Insecticide Distribution	
Calcium Arsenate Pesticide Containers	5800	290		870		1914		2030	174	522	Pesticide Distribution	
					Stored Waste #							
Contaminated Soil									2.6×10^9		Rocky Mountain Arsenal Basin A	2222
Recovered Dust from Refinery Flues										4×10^7	ASARCO Storage	
Pesticide	2.6×10^4							1.6×10^3		2.4×10^4	Bagged Pesticide	2243, 2222
Contaminated Soil (0-600 ppm)		5%		15%		33%		35%	3%	9%	Total Quantity Unknown	2271
Arsenic Trichloride Still Bottoms										1.6×10^4	Aerojet General	1643
Copper Acetoarsenite Paris Green						3×10^4					Military	2222

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EXPLOSIVE WASTE GENERATION ESTIMATE

The attached table lists explosive manufacturing wastes disposed of by open burning or detonation at both civilian and military manufacturing installations. The listing and quantities are not complete, nor are they to be considered final, since much of the information on military facilities is not currently available.

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EXPLOSIVE MANUFACTURING WASTES

POUNDS PER DAY SOLID WASTE EXPLOSIVE/EXPLOSIVE CONTAMINATED WASTE

State	Nitrocellulose Based Propellant *	Propellant Contaminated Waste	Nitroglycerin and NG Mixtures	NG Contaminated Waste	Industrial Propellant/ Explosives	Industrial Explosives Contaminated Waste	Military** High Explosives	Military H.E. Contaminated Waste	Primary Explosive Compositions	Primary Explosives Contaminated Waste	Pyrotechnics***	Pyrotechnic Contaminated Waste
New York									[I]	[I]		
New Jersey	1,000	1,000			20				220	650		
Pennsylvania					125	750				415		
Virginia	7,850	11,900	800	800			7,850	11,900				
Alabama			125	200					5	2		
Tennessee							32		32			
Lousiana							4,500					
Arkansas											1,500	1,750
Texas											59	
Illinois			10		100	1,000						
Wisconsin	4,994											
Ohio			15						[I]			
Indiana	165								165			
Missouri	600		200	150		48			600			
Nebraska	600	165					600	165				
Kansas							5,128	20,800	378	9,900		
Iowa							25,000					
Minnesota	60	40										
Utah			10		50	250						
Colorado												
Washington			525	750								

*Includes single and multi-base propellants and smokeless powder

**Includes TNT, TDX, HMX, PETN, TETRYL, etc.

***Includes white phosphorus compositions

[I] Amount not known

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APPENDIX D - PROFILE REPORTS SUMMARY

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HAZARDOUS WASTE

* IN ALL CASES, ARE LISTED IN RANK PREFERENCE

MATL NO	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED * TREATMENT
8	ACROLEIN (28,29)	YES	3	3 (p. 43)	CONCENTRATED: RETURN TO SUPPLIER (RECYCLE) OR INCINERATION DILUTE: COMBUSTION
13	ALDRIN (28,29)	YES	5	5 (p. 144)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN), CHEMICAL OXIDATION, ANAEROBIC DEGRADATION
15	ALLYL CHLORIDE (29)	NO	6	5 (p. 170)	CONCENTRATED: INCINERATION WITH HCL REMOVAL DILUTE: (ORGANIC) INCINERATION (AQUEOUS) INCINERATION WITH HCL & REMOVAL
16	ALUMINUM FLUORIDE (33)		5		
21	AMMONIUM CHROMATE	YES	4	4 (p. 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
22	AMMONIUM DICHROMATE (28)	YES	4	4 (p. 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
23	AMMONIUM FLUORIDE (28)	NO	5	6 (p. 25)	LIME SLURRY, LAGOONING, RECOVERY OR LANDFILL (LARGE SITES) SLAKED LIME, NEUTRALIZATION & LANDFILL (MODERATE LOTS & SMALL)
33	ANTIMONY (28)	NO	5	5 (p. 177)	RECYCLED AND/OR NOT CONSIDERED HAZARDOUS
34	ANTIMONY, POWDERED (28)	NO	5	5 (p. 177)	RECYCLED AND/OR NOT CONSIDERED HAZARDOUS
36	ANTIMONY PENTAFLUORIDE (28)	YES	5	6 (p. 47)	RETURN TO SUPPLIER (RECYCLE), OR PRECIPITATION W/HYDROGEN SULFIDE
43	ANTIMONY TRIFLUORIDE (28)	YES	5	6 (p. 47)	RETURN TO SUPPLIER (RECYCLE), OR PRECIPITATION W/HYDROGEN SULFIDE
45	ANTIMONY TRIOXIDE	NO	—	5 (p. 177)	RECYCLED AND/OR NOT CONSIDERED HAZARDOUS
46	ARSENIC (28,31, DOD)	NO	4	4 (p. 41)	RETURN TO SUPPLIER (RECYCLE), OR DOES NOT OCCUR AS A WASTE PRODUCT
50	ARSENIC TRICHLORIDE (28)	YES	5	5 (p. 188)	RETURN TO SUPPLIER (RECYCLE/REPROCESS), LONG TERM STORAGE LANDFILL IS ADEQUATE BUT NOT RECOMMENDED
51	ARSENIC TRIOXIDE (28)	YES	5	5 (p. 195)	RECYCLING/REPROCESSING BY AMERICAN SMELTING & REFINING CO. LONG TERM STORAGE (NATIONAL DISPOSAL SITE), LANDFILL IS APPARENTLY ADEQUATE BUT NOT RECOMMENDED WHERE LARGE OVERSTOCKS OF As_2O_3 ARE PRESENT
52	BARIUM CARBONATE (28)	NO	5	6 (p. 57)	PRECIPITATION WITH SULFATE ION (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
53	BARIUM CHLORIDE (28)	NO	5	6 (p. 57)	PRECIPITATION WITH SULFATE ION (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
55	BENZENE HEXACHLORIDE (LINDANE)	YES	5	5 (p. 206)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN) COAGULATION & FILTRATION FOR DDT OR DDD, ALKALINE HYDROLYSIS, AND ANAEROBIC DEGRADATION
58	BENZYL CHLORIDE (28)	NO	6	6 (p. 75)	CONCENTRATED: INCINERATION W/SCRUBBER (HYDROGEN CHLORIDE REMOVAL) DILUTE AQUEOUS: CONVERSION TO ALCOHOL, ACTIVATED SLUDGE, OR SORPTION PLUS BURIAL DILUTE ORGANIC: INCINERATION W/SCRUBBER, OR SORPTION PLUS BURIAL
59	BERYLLIUM, POWDER (28)	NO	5	5 (p. 230)	RECOVERY/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE
60	BORIC ACID		9		
61	BORON HYDRIDES (28, DOD)	YES	6	6 (p. 83)	INCINERATION W/SCRUBBER, OR HYDROLYSIS
63	BORON TRIFLUORIDE (28)	NO	3	3 (p. 51)	RECYCLED, OR WATER SPRAY/LIME TREATMENT, LANDFILL, LAGOONED
64	BROMIC ACID (28)		7		
65	BROMINE (28)	NO	5	4 (p. 45)	RECOVERY PROCESS BY SUPPLIER FOR REUSE OR SALE IS PRESENTLY DONE & IS ADEQUATE
66	BROMINE PENTAFLUORIDE	YES	3	3 (p. 50)	CHARCOAL PACKED REACTOR, OR DILUTION CONVERSION TO CHLORINE/BROMINE
77	BUTYL MERCAPTAN (28,29)	NO	5	5 (p. 246)	CONCENTRATED: (GAS) FLARE BURNING OR ACTIVATED CARBON SCRUBBER (LIQUID) INCINERATION W/SCRUBBER, OR RECYCLE DILUTE: INCINERATION W/SCRUBBER

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PART NO	H.W. MATERIAL	NATIONWIDE CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
80	CACODYLIC ACID	NO	6	8	LONG TERM STORAGE; RECYCLE/REUSE (RETURNED TO SUPPLIERS FOR RESALE); LANDFILL (ONLY IF STORED STOCKS BECOME TOO LARGE)
81	CADMIUM (34, DOD)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
82	CADMIUM, POWDERED (28)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
83	CADMIUM CHLORIDE (347)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED, COAGULATION & FILTRATION, ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
84	CADMIUM CYANIDES (347)	YES	5	5 (p. 258)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
85	CADMIUM OXIDE FUME (28)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED, COAGULATION & FILTRATION, ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
86	CADMIUM PHOSPHATE (33, 34)	YES	7	7 (p. 67)	ACTIVATED-CARBON BED, COAGULATION & FILTRATION, ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
87	CALCIUM ARSENATE (28)	YES	5	5 (p. 285)	LONG TERM STORAGE, RECYCLE/REUSE, RECOVERY
88	CALCIUM ARSENITE (28, DOD)	YES	6	6 (p. 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
91	CALCIUM CYANIDE	YES	—	5 (p. 258)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
101	CARBONYL CHLORIDE (PHOSGENE) (28)	YES	4	4 (p. 51)	REACTION WITH STEAM/NH_3, CO_2 SCRUBBING; CAUSTIC SCRUBBING; REACTION WITH ALCOHOL
105	CHLORINE (26)	YES	5	5 (p. [illegible])	RECOVERY/REUSE, ALKALINE SCRUBBING; WATER SCRUBBING, CARBON TETRACHLORIDE SCRUBBING
106	CHLORINE TRIFLUORIDE & CHLORINE PENTAFLUORIDE (2872)	YES	3	3 (p. 66)	PACKAGE BURNER; WATER SPRAY; REACTION W/SODIUM CHLORIDE, (INDUSTRIAL SITE) REACTION W/CHARCOAL BED AT NATIONAL DISPOSAL SITE
107	CHLOROACETOPHENONE	YES	6	7 (p. 93)	INCINERATION (WHEN PACKAGED W/EASILY COMBUSTIBLE MATERIALS); REACTION W/SODIUM SULFIDE
111	CHLOROPICRIN (28)	NO	5	6 (p. 131)	CONCENTRATED: RECYCLE (TO SUPPLIERS) OR INCINERATION W/SCRUBBER DILUTE: (AQUEOUS) (IF REACTED W/SODIUM SULFITE OR SODIUM BISULFITE + SLUDGE INCINERATED) (ORGANIC): INCINERATION W/SCRUBBER
112	CHLOROSULFONIC ACID (DOD)	NO	6	7 (p. 99)	NEUTRALIZED & DISCHARGED INTO STREAM OR STORM SEWER.
113	CHROME (22)	NO	6	6 (p. 137)	RECYCLE FOR USE IN NEW PRODUCTS. NOT CONSIDERED A HAZARD.
114	CHROMIC ACID (LIQUID, CHROMIUM TRIOXIDE) (247, 28)	YES	6	6 (p. 143)	RECYCLE OR REDUCTION/PRECIPITATION
119	COPPER ARSENATES (28)	YES	5	5 (p. 285)	LONG TERM STORAGE, RECYCLE/REUSE, RECOVERY
120	COPPER CYANIDES (347, 29)	YES	5	5 (p. 258)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
121	COPPER NITRATE (22, 27, 347)		9		
129	CYANIDES (2834, 29)	YES	5	5 (p. 258)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
135	2,4-D (2,4-DICHLOROPHENOXYACETIC ACID) (29)	YES	6	6 (p. 153)	CONCENTRATED: INCINERATION W/CHLORINE RECOVERY, SOIL SURFACE APPLICATION DILUTE: ACTIVATED-CARBON BED (GRAN); ACTIVATED CARBON (POWDERED), BIOLOGICAL DEGRADATION, ION EXCHANGE
136	DDD (28)	YES	5	5 (p. 204)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN) COAGULATION & FILTRATION FOR DDT or DDD ALKALINE HYDROLYSIS & ANAEROBIC DEGRADATION
137	DDT (28, 29)	YES	5	5 (p. 204)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN) COAGULATION & FILTRATION FOR DDT or DDD ALKALINE HYDROLYSIS & ANAEROBIC DEGRADATION
149	DIELDRIN (28, 29)	YES	5	5 (p. 149)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN)

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MAT'L NO	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED Completion Date	ACTUAL Completion Date	RECOMMENDED TREATMENT
160	DIMETHYL SULFATE (METHYL SULFATE)	YES	5	(p 58)	INCINERATION, DILUTION, NEUTRALIZATION, OR WASTE WATER TREATMENT (ONLY FOR VERY DILUTE STREAMS)
162	DINITRO CRESOLS (28)	YES	6	6 (p 131)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN)
163	DINITROBENZOL (DINITROBENZENE)(28)	NO	4	4 (p 64)	CONCENTRATED: INCINERATION W/SCRUBBER DILUTE (AQUEOUS) CONCENTRATE & TREAT SAME AS ABOVE
164	DINITROPHENOL (28)	NO	4	4 (p 72)	CONCENTRATED: RETURN TO SUPPLIER (RECYCLE) OR INCINERATION DILUTE (AQUEOUS) CONCENTRATE & TREAT SAME AS ABOVE
165	DINITROTOLUENE (DINITROTOLUOL)(28)	YES	5	5 (p 318)	INCINERATION W/SCRUBBER
167	DIPHENYLAMINE (PHENYLANILINE)(28)	NO	5	5 (p 326)	CONCENTRATED: INCINERATION W/SCRUBBER, LANDFILL DILUTE: LANDFILL
170	ENDRIN (28, 29)	YES	5	5 (p 141)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN), ANAEROBIC DEGRADATION
182	ETHYLENE BROMIDE (182)	YES	6	6 (p 185)	REMOVAL FROM AIR: REFRIGERATED CONDENSATION " " WATER: STEAM STRIPPING & BLOWING WITH AIR CONCENTRATED: INCINERATION/RECOVERY (OF HALOGENS)
190	ETHYLENIMINE (28, 29)	NO	5	5 (p 328)	DILUTE (ORGANIC): INCINERATION W/SCRUBBER DILUTE (AQUEOUS): POLYMERIZATION/AERATION & ACTIVATED SLUDGE CONCENTRATED: INCINERATION
192	ETHYL MERCAPTAN (26, 28)	NO	5	5 (p 246)	CONCENTRATED: (GAS) FLARE BURNING OR ACTIVATED CARBON [illegible] (LIQUID) INCINERATION W/SCRUBBER, OR RECYCLE DILUTE: INCINERATION W/SCRUBBER
200	FLUORINE (10, 28, DOD)	YES	3	3 (p 75)	REACTION W/CHARCOAL BED, OR BURNING W/FUEL (GASEOUS STATE)
212	HYDRAZINE (20, 28, DOD) (ANHYDROUS DIAMINE)	NO	5	6 (p 213)	CONCENTRATED: INCINERATION, OPEN PIT BURNING DILUTE: NOT CONSIDERED A HAZARD
213	HYDROBROMIC ACID	NO	—	5 (p 335)	RECOVERY & CONVERSION TO BROMINE BY CHLORINATION
220	HYDROQUINONE (20, 28, 29, 34)	NO	5	5 (p 346)	WASTE WATER TREATMENT OR INCINERATION
221	HYDROGEN SULFIDE	YES	—	2 (p 33)	CLAUS-BEAVON PROCESS OR TRW S-100 PROCESS
233	LEAD (DOD)	NO	6	7 (p 85)	RECLAMATION: MELTING INTO INGOTS (IF SCRAP IS PURE OR NEARLY PURE) RECOVERY IN LEAD BLAST FURNACE RECOVERY FROM BLAST FURNACE FUME
234	LEAD ACETATE (22, 28)	NO	7	8	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE, CONVERSION TO SULFIDE, LANDFILL (INSOLUBLE COMPOUNDS ONLY)
235	LEAD ARSENATE (28)	YES	5	5 (p 285)	LONG TERM STORAGE, RECYCLE/REUSE, RECOVERY
236	LEAD ARSENITE (28)	YES	6	6 (p 111)	LONG TERM STORAGE, RECYCLE/REUSE, RECOVERY
237	LEAD CARBONATE (28)	NO	7	8	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE, CONVERSION TO SULFIDE, LANDFILL (INSOLUBLE COMPOUNDS ONLY)
238	LEAD CHLORITE (28)	NO	7	8	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE, CONVERSION TO SULFIDE, LANDFILL (INSOLUBLE COMPOUNDS ONLY)
239	LEAD CYANIDE (347)	YES	5	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)

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MATL NO	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
240	LEAD NITRATE (22,28,31,DOD)	NO	7	8	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE, CONVERSION TO SULFIDE, LANDFILL (INSOLUBLE COMPOUNDS ONLY)
241	LEAD NITRITE	NO	7	8	DILUTE: CARBONATE OR SULFIDE PRECIPITATION CONCENTRATED: RECYCLE, CONVERSION TO SULFIDE, LANDFILL (INSOLUBLE COMPOUNDS ONLY)
242	LEAD OXIDE (28,29,31)		7		
243	LEWISITE		7		
245	MAGNESIUM ARSENITE (DOD)		7		
249	MALEIC ANHYDRIDE (20,28)	NO	3	3 (p. 83)	CONCENTRATED: RECYCLE, OR INCINERATION DILUTE: INCINERATION (TAR BYPRODUCTS) NEUTRALIZATION/MUNICIPAL SEWERS (MALEIC ACID)
252	MANGANESE SULFATE (30,28)	NO	7	8	(NONTOXIC) INSOLUBLE RESIDUES: LANDFILL; LAGOONING CONVERSION TO MANGANESE SULFATE FOR USE AS FERTILIZER
253	MERCURIC CHLORIDE (28,34,31,32)	YES	6	7 (p. 113)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS; VENTRON SODIUM BOROHYDRIDE PROCESS
254	MERCURIC CYANIDE (28)	YES	5	6 (p. 221)	ALKALINE CHLORINATION/SODIUM BOROHYDRIDE REDUCTION, OR CHLORINATION/ION EXCHANGE
255	MERCURIC NITRATE (28)	YES	6	7 (p. 113)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS; VENTRON SODIUM BOROHYDRIDE PROCESS
256	MERCURIC SULFATE (28,10,36)	YES	6	7 (p. 113)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS, VENTRON SODIUM BOROHYDRIDE PROCESS
257	MERCURY (22,26, DOD)	YES	6	7 (p. 113)	RECOVERY/REMOVAL FROM GASES — UNION CARBIDE PURASIV HG SYSTEM (ADSORPTION W/MOLECULAR SIEVES); SODIUM HYPOCHLORITE SCRUBBING RECOVERY/REMOVAL FROM LIQUIDS — AKTIEBOLAGET BILLINGSFORS-LANGED PROCESS, VENTRON SODIUM BOROHYDRIDE PROCESS
258	MERCURY COMPOUNDS (ORGANIC) (28)	YES	6	8	DILUTE: (AQUEOUS) REDUCTION W/SODIUM BOROHYDRIDE & RECOVERY OF METALLIC MERCURY CONCENTRATE ORGANIC: INCINERATION W/MERCURY VAPOR SCRUBBER
267	METHYL BROMIDE	YES	6	6 (p. 185)	REMOVAL FROM AIR: REFRIGERATED CONDENSATION " " WATER: STEAM STRIPPING & BLOWING WITH AIR CONCENTRATED: INCINERATION/RECOVERY (OF HALOGENS)
268	METHYL CHLORIDE	YES	6	6 (p. 185)	REMOVAL FROM AIR: REFRIGERATED CONDENSATION " WATER: STEAM STRIPPING & BLOWING WITH AIR CONCENTRATED: INCINERATION/RECOVERY (OF HALOGENS)
272	METHYL MERCAPTAN (METHANETHIOL) (26)	NO	5	5 (p. 296)	CONCENTRATED: (GAS) FLARE BURNING, OR ACTIVATED CARBON SCRUBBER (LIQUID) INCINERATION W/SCRUBBER, OR RECYCLE DILUTE: INCINERATION W/SCRUBBER
274	METHYL PARATHION	YES	4	4 (p. 83)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED; ACTIVATED SLUDGE, ALKALINE HYDROLYSIS
287	NERVE GAS (GB,DOD) (NON-PERSISTENT)	YES	5	5 (p. 301)	CONCENTRATED: INCINERATION (TRANSPORTABLE DISPOSAL SYSTEM) DILUTE: HYDROLYSIS (POSSIBLE RESTRICTIONS ON VX)
288	NERVE GAS (VX) (PERSISTENT) (DOD)	YES	5	5 (p. 301)	CONCENTRATED: INCINERATION (TRANSPORTABLE DISPOSAL SYSTEM) DILUTE: HYDROLYSIS (POSSIBLE RESTRICTIONS ON VX)
289	NICKEL (DOD)		5		
290	NICKEL AMMONIUM SULFATE (347)	NO	7	7 (p. 168)	RECYCLE/REUSE; PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS, DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY REGULATIONS)
291	NICKEL ANTIMONIDE (28)	NO	7	7 (p. 185)	RETURN TO SUPPLIER, ENCAPSULATION/LANDFILL

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MAT'L NO.	N.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
292	NICKEL ARSENIDE (28)	NO	7	7 (p.105)	RETURN TO SUPPLIER; ENCAPSULATION/LANDFILL
293	NICKEL CARBONYL (28)	YES	5	5 (p. [illegible])	LARGE QUANTITIES: RECYCLE SMALL QUANTITIES: THERMAL DECOMPOSITION & WET SCRUBBING
294	NICKEL CHLORIDE (347)	NO	7	7 (p.129)	RECYCLE/REUSE; PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS; DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY REGULATIONS)
295	NICKEL CYANIDE (347)	YES	5	5 (p.259)	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (NICKEL, CYANIDE) (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
296	NICKEL NITRATE (347)	NO	7	7 (p.129)	RECYCLE/REUSE; PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS; DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY REGULATIONS)
297	NICKEL SELENIDE (28)	NO	7	7 (p.155)	RETURN TO SUPPLIER; ENCAPSULATION/LANDFILL
298	NICKEL SULFATE (22, 28, 347)	NO	7	7 (p.129)	RECYCLE/REUSE; PRECIPITATION/CLARIFICATION/LANDFILL OR SEWERS; DIRECT DISCHARGE TO MUNICIPAL SEWERS (IF AT A CONTROLLED RATE & SEWAGE TREATMENT PLANT CAN EFFECTIVELY COMPLY WITH PURITY REGULATIONS)
300	NITROANILINE (META-, PARA-NITROANILINE) (22)	NO	5	4 (p.110)	CONCENTRATED: INCINERATION W/SCRUBBERS (IF PURIFICATION/RECYCLING IS IMPRACTICAL) DILUTE (AQUEOUS): CONCENTRATE & TREAT AS ABOVE. ACTIVATED SLUDGE TREATMENT RESEARCH IS NEEDED. (WASTES PRIMARILY APPEAR AS AQUEOUS)
301	NITROBENZENE (NITROBENZOL) (28)	NO	4	4 (p.118)	CONCENTRATED: RECYCLE; OR INCINERATION OF SMALL AMOUNTS DILUTE: ACTIVATED SLUDGE
302	NITROCHLOROBENZENE (META-, OR PARA-) (22, 28)	NO	6	6 (p. [illegible])	CONCENTRATED: INCINERATION W/SCRUBBERS; LANDFILL DILUTE ORGANIC: " " " DILUTE AQUEOUS: INCINERATION
306	NITROGEN MUSTARD (HN) (DOD)	YES	5	6 (p. [illegible])	INCINERATION (TRANSPORTABLE DISPOSAL SYSTEM); CHEMICAL REACTION WITH HYPOCHLORITE FOR SMALLER QTIES.
307	NITROGLYCERIN (DOD)	YES (in small qty. [illegible])	5	5 (p.572)	CONTROLLED INCINERATION W/SCRUBBERS (OF SAFE LOT SIZES); ALKALI SULFIDES (FOR MINUTE QUANTITIES) - SUCH AS CLEANING EQUIPMENT
317	OXALIC ACID (28)	NO	4	4 (p.125)	NEUTRALIZATION (LIMESTONE)/INCINERATION/RECYCLE (INCINERATORS EQUIPPED WITH PARTICULATE REMOVAL DEVICES)
321	PARATHION (28)	YES	4	4 (p.23)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED; ACTIVATED SLUDGE; ALKALINE HYDROLYSIS
322	PENTACHLOROPHENOL (28)		6		
324	PERCHLORIC ACID (TO 72% STRENGTH) (22, DOD)		7		
326	PERCHLORYL FLUORIDE (28, 2072)	YES	7	7 (p.195)	REACTION W/CHARCOAL BED
332	PHOSPHORUS WHITE OR YELLOW (WP) (DOD)		5		
333	PHOSPHORUS OXYCHLORIDE (28, 29)	NO	7	8	DECOMPOSITION; NEUTRALIZATION; RECYCLE (ALL THREE ARE EQUALLY EFFECTIVE)
334	PHOSPHORUS PENTACHLORIDE (28)	NO	7	8	DECOMPOSITION; NEUTRALIZATION; RECYCLE (ALL THREE ARE EQUALLY EFFECTIVE)
335	PHOSPHORUS PENTASULFIDE (28, 29)	NO	7	8	LARGE QUANTITIES: DECOMPOSITION W/WATER; INCINERATION SMALL QUANTITIES: DECOMPOSITION W/WATER; BURIAL
336	PHOSPHORUS TRICHLORIDE (22, 28, 29)	NO	7	8	DECOMPOSITION; NEUTRALIZATION; RECYCLE (ALL THREE ARE EQUALLY EFFECTIVE)

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MATL NO.	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
338	Picric Acid (28X DoD) (Trinitro-phenol Liquid)	YES - (Small Quantities)	5	8	[illegible] REACTION IN DILUTE SOLUTION (TRENCHED IF INDUSTRIAL SITE) CONCENTRATED (CONTAMINATED) SAME AS DILUTE. IF NOT CONTAMINATED, RECOVER/RECYCLE.
341	Potassium Arsenite (28)	YES	6	6 (p 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
343	Potassium Chromate (28)	YES	4	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
344	Potassium Cyanide, Solid (347, 28)	YES	5	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY.)
345	Potassium Dichromate (19, 22, 26, 28, [illegible])	YES	4	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
346	Potassium Fluoride	NO	5	6 (p 25)	LIME SLURRY, LAGOONING, RECOVERY OR LANDFILL. (LARGE QTIES) SLAKED LIME, NEUTRALIZATION & LANDFILL (PACKAGE LOTS & SPILLS)
349	Potassium Permanganate (DoD)		6		
350	Potassium Peroxide (28, DoD)	NO	—	5 (p 377)	NEUTRALIZATION/DISCHARGED INTO RIVER
365	Quinone (22)	NO	5	5 (p [illegible])	INCINERATION; ACTIVATED SLUDGE (WITH PRIOR REDUCTION TO HYDROQUINONE OR HYDROQUINONE DERIVATIVE)
367	Selenium, Powdered (28, 33)	NO	5	5 (p [illegible])	RECOVERY/RECYCLE
370	Silver Cyanides (28, 347)	YES	5	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY.)
374	Sodium Alloy	NO	—	2 (p 97)	PLACED IN PERFORATED DRUMS AND DUMPED AT SEA; OR BURNING W/KEROSENE IN A CLOSED CHEMICAL REACTOR; OR PACKED IN BARRELS/CONCRETE COLLARS AND DUMPED AT SEA
376	Sodium Arsenate (28)	YES	5	5 (p [illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
377	Sodium Arsenite (28)	YES	6	6 (p 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
378	Sodium Azide (28, [illegible])	NO	6	6 (p [illegible])	REACTION W/SULFURIC ACID & SODIUM NITRATE
379	Sodium Bichromate (Sodium Dichromate) (22, 31, 32, 347)	YES	6	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
382	Sodium Cacodylate (28)	NO	6	6	LONG TERM STORAGE; RECYCLE/REUSE (RETURNED TO SUPPLIERS FOR RESALE); LANDFILL (ONLY IF STORED STOCKS BECOME TOO LARGE)
386	Sodium Chromate (22, 28, 31)	YES	4	4 (p 16)	REDUCTION/PRECIPITATION & ION EXCHANGE
387	Sodium Cyanide (28, 347)	YES	5	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY.)
389	Sodium Fluoride (28, 33, 347)	NO	5	6 (p 25)	LIME SLURRY, LAGOONING, RECOVERY OR LANDFILL. (LARGE QTIES) SLAKED LIME, NEUTRALIZATION & LANDFILL (PACKAGE LOTS & SPILLS)
400	Sodium Peroxide (22, 26, 28)	NO	—	5 (p 377)	(ONLY ONE MANUFACTURER IN U.S. — PEROXIDE IS PRODUCED BY CONTROLLED OXIDATION OF SODIUM METAL WITH NO WASTES)
402	Sodium Potassium Alloy	NO	—	2 (p 97)	PLACED IN PERFORATED DRUMS AND DUMPED AT SEA; OR BURNING W/KEROSENE IN A CLOSED CHEMICAL REACTOR; OR PACKED IN BARRELS/CONCRETE COLLARS, AND DUMPED AT SEA
410	Strontium	NO	—	5 (p 399)	CONCENTRATED: PURIFICATION/RECYCLED DILUTE: MINUTE QTIES. WASHED DOWN DRAIN. H_2 GAS EVOLVED SLOWLY & IS KEPT WELL BELOW FLAMMABLE LIMIT. (NOTE ONLY [illegible] WORLD ANNUAL PRODUCTION)

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MATL. NO.	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
422	TEAR GAS (CN)(DOD)	YES	5	7 (p 98)	INCINERATION (WHEN PACKAGED W/EASILY COMBUSTIBLE MATERIALS; REACTION W/SODIUM SULFIDE
423	TEAR GAS, IRRITANT (CS)(DOD)	YES	5	8	HYDROLYZE WITH 95% ETHANOL, AND BURN REACTION PRODUCT IN INCINERATOR EQUIPPED WITH ALKALINE SCRUBBER
425	TETRAETHYL LEAD (ALL MIXES) (28,29)	NO	5	6 (p. [illegible])	INCINERATION W/SCRUBBER, & RECYCLE; ION EXCHANGE; IMPROVED PRECIPITATION/REUSE (NOTE: PRESENT METHODS ARE NOT COMPLETELY ACCEPTABLE & INTENSIVE STUDY HAS BEEN MADE CONCLUDING WITH THE ARMY [illegible])
427	TETRAMETHYL LEAD (29)	NO	5	6 (p. [illegible])	SAME AS TETRAETHYL LEAD (425).
428	TETRANITROMETHANE (DOD)	NO	3	3 (p 91)	RETURN TO SUPPLIER/RECYCLE; ENCLOSED PIT BURNING W/BLOWERS--GASES ARE PASSED THROUGH LOOSELY PACKED EARTH OR THROUGH WET SCRUBBERS.
453	ZINC ARSENATE (28)	YES	5	5 (p [illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
454	ZINC ARSENITE (28)	YES	6	6 (p 111)	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
455	ZINC CHLORATE (28,33,34)		7		WILL BE DONE AS CATEGORY II.
457	ZINC CYANIDE	YES	—	5 (p [illegible])	OXIDATION BY CHLORINATION AND/OR RECOVERY PROCESS (WATER, CYANIDE). (ADDITIONAL RESEARCH NEEDED FOR METAL RECOVERY)
458	ZINC ETHYL (28)		7	}	
459	ZINC NITRATE (28)		7		
461	ZINC PERMANGANATE (28)		7		WILL BE DONE AS CATEGORY II.
462	ZINC PEROXIDE (28)		7		
463	ZINC SULFITE (28)		7		
469	BARIUM CYANIDE	NO	5	6 (p 57)	PRECIPITATION WITH SULFATE ION. (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
470	BARIUM FLUORIDE		5		
471	BARIUM NITRATE	NO	5	6 (p 57)	PRECIPITATION WITH SULFATE ION. (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
472	BARIUM SULFIDE	NO	5	6 (p 57)	PRECIPITATION WITH SULFATE ION. (ADEQUATELY HANDLED AT INDUSTRIAL SITE LEVEL)
473	BERYLLIUM CARBONATE	NO	5	5 (p 23[illegible])	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.
474	BERYLLIUM CHLORIDE	NO	5	5 (p 23[illegible])	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.
475	BERYLLIUM HYDROXIDE	NO	5	5 (p 23[illegible])	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.
476	BERYLLIUM OXIDE	NO	5	5 (p 23[illegible])	RECOVER/RECYCLE OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.

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PROF. NO.	H.W. MATERIAL	NATIONAL DISPOSAL	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
477	BERYLLIUM SELENATE	NO	5	5 (p. [illegible])	RECOVERY/RECYCLE; OR LANDFILL (AFTER INCINERATION) VERY ADEQUATE.
478	CADMIUM FLUORIDE		5		
479	CADMIUM NITRATE	YES	7	7 (p.67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
480	CADMIUM POTASSIUM CYANIDE	YES	7	7 (p.67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
481	CADMIUM SULFATE	YES	7	7 (p.67)	ACTIVATED-CARBON BED; COAGULATION & FILTRATION; ION EXCHANGE W/CRITICAL DEPENDENCE ON FLOWRATE
484	CHLORDANE	YES	5	5 (p. [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.), ACID HYDROLYSIS, CHEMICAL OXIDATION, ANAEROBIC DEGRADATION
485	CHROMIC FLUORIDE	NO	6	7 (p.213)	PRECIPITATION; DILUTION/DISCHARGE INTO MUNICIPAL SEWERS
486	CHROMIC SULFATE	NO	6	7 (p.213)	PRECIPITATION; DILUTION/DISCHARGE INTO MUNICIPAL SEWERS
487	CHROMIC CYANIDE	NO	6	7 (p.213)	DOES NOT EXIST AS A COMPOUND
490	COPPER ACETOARSENITE	YES	6	6 (p. [illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
491	DEMETON	YES	4	4 (p.82)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON BED; ACTIVATED SLUDGE; ALKALINE HYDROLYSIS
495	GUTHION	YES	4	4 (p.83)	CONCENTRATED: INCINERATION DILUTE: ACTIVATED-CARBON BED; ACTIVATED SLUDGE; ALKALINE HYDROLYSIS
496	HEPTACHLOR	YES	5	5 (p. [illegible])	CONCENTRATED: INCINERATION DILUTE: ACTIVATED CARBON (POWDERED OR GRAN.), CHEMICAL OXIDATION, ANAEROBIC DEGRADATION
499	MANGANESE	NO	6	7 (p. [illegible])	LANDFILL IS ADEQUATE, & NOT CONSIDERED HAZARDOUS. HOWEVER, IMPROVED DUST CONTROL IS HIGHLY RECOMMENDED
500	MANGANESE ARSENATE	YES	5	5 (p. [illegible])	LONG TERM STORAGE; RECYCLE/REUSE, RECOVERY
501	MANGANESE CHLORIDE	NO	7	8	(NONTOXIC) INSOLUBLE RESIDUES: LANDFILL, LAGOONING CONVERSION TO MANGANESE SULFATE FOR USE AS FERTILIZER.
502	MANGANESE METHYLCYCLOPENTADIENYLTRICARBONYL	NO	7	7 (p. [illegible])	OIL STREAMS - INCINERATION/[illegible]; INCINERATION/VENTING IF EMISSION LEVEL IS ACCEPTABLE WATER STREAMS - SETTLING POND WITH LIME ADDED
503	MERCURIC DIAMMONIUM CHLORIDE	YES	6	7 (p.118)	[illegible] FROM GASES — [illegible] W/MOLECULAR [illegible] SODIUM HYPOCHLORITE SCRUBBING [illegible] FROM LIQUIDS — [illegible] PROCESS; VENTRON SODIUM BOROHYDRIDE PROCESS
505	PENTABORANE	YES	6	6 (p. [illegible])	INCINERATION W/SCRUBBER OR HYDROLYSIS
507	POLYCHLORINATED BIPHENYLS (ASKARELS)	NO	5	5 (p. [illegible])	CONCENTRATED: RETURN TO SUPPLIER DILUTE (SOLID): HIGH TEMP. INCINERATION W/SCRUBBER " (LIQUID ORGANIC): RETURN TO SUPPLIER " [illegible] " [illegible] RETURN TO SUPPLIER
508	SODIUM OXIDE	NO		5 (p.277)	(SAME TREATMENT AS SODIUM WASTES)
514	BENZOYL PEROXIDE		7		
515	1,2,4-BUTANETRIOL TRINITRATE (BTTN)		7		

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MAT'L NO.	H.W. MATERIAL	NATIONAL CANDIDATE	SCHEDULED COMPLETION DATE	ACTUAL COMPLETION DATE	RECOMMENDED TREATMENT
516	CHLORATES WITH RED PHOSPHORUS		7		
517	COPPER ACETYLIDE	YES	7	8	INTERIM DISPOSAL - DETONATION AT NATIONAL DISPOSAL SITE. OR IF TOO HAZARDOUS TO TRANSPORT, IN CLEARED AREA. RESEARCH ON ALTERNATIVE DISPOSAL REQUIRED.
518	COPPER CHLOROTETRAZOLE		7		
519	CYANURIC TRIAZIDE	NO	7	8	DETONATION BY TRAINED ORDNANCE PERSONNEL.
520	DETONATORS	YES	7	8	DESTRUCTION IN SPECIAL DETONATOR DESTRUCTION FURNACE EQUIPPED WITH SCRUBBING DEVICES, IF SAFE FOR TRANSPORT.
521	DIAZODINITROPHENOL (DDNP)	YES	7	8	IF SAFE, CONTROLLED INCINERATION OF WATER SLURRY OF DDNP (IF IMPOSSIBLE TO HANDLE CONTAMINATED WASTE AS SLURRY, CHEMICAL DECONTAMINATION) IF UNSAFE, DETONATION IN CLEARED AREA.
522	DIPENTAERYTHRITOL-HEXANITRATE (DPEHN)	YES	7	8	IF SAFE, USE CONTROLLED INCINERATION IN ROTARY KILN EQUIPPED WITH SCRUBBERS. IF UNSAFE, DETONATION IN CLEARED AREA.
523	GELATINIZED NITROCELLULOSE	YES	7	8	CONTROLLED INCINERATION, IN SYSTEM EQUIPPED WITH AFTERBURNER AND SCRUBBERS.
524	GLYCEROL MONOLACTATE TRINITRATE (GLTN)		7	8	
525	GLYCOL DINITRATE (DDN)	YES- as Dynamite	7	8	CONTROLLED INCINERATION w/SCRUBBER
526	GOLD FULMINATE (FULMINATING GOLD)		7		
527	HYDRAZINE AZIDE/ HYDRAZINE		7		
528	HYDRAZOIC ACID	NO	7	7 (p. 20)	DILUTION/NEUTRALIZATION/STORM SEWERS OR STREAM. (CONSIDERED TOO HAZARDOUS FOR SHIPMENT)
529	LEAD AZIDE	YES	7	8	DISPOSAL BY ELECTROLYSIS, IF SAFE; IF UNSAFE, DETONATION IN CLEARED AREA.
530	LEAD 2,4 DINITRORESORCINATE (LDNR)		7		
531	LEAD STYPHNATE (LEAD TRINITRORESORCINATE)	YES	7	8	IF SAFE, USE CONTROLLED INCINERATION IN ROTARY KILN EQUIPPED WITH SCRUBBERS. IF UNSAFE, DETONATION IN CLEARED AREA.
532	MANNITOL HEXANITRATE	YES	7	8	IF SAFE, DETONATE OR BURN AT N.D.S. (UNTIL RESEARCH DEVELOPS BETTER TECHNIQUE) IF UNSAFE, DETONATE OR BURN IN NEAREST CLEARED AREA.
533	MERCURIC FULMINATE (FULMINATE OF MERCURY)	NO	7	8	WET DECOMPOSITION BY AQUEOUS $Na_2S_2O_3$
534	NITROCELLULOSE		7	8	
535	POLYVINYL NITRATE (PVN)		7	8	
536	POTASSIUM DINITROBENZOFUROXAN (KDNBF)	YES	7	8	DESTROYED BY CONTROLLED INCINERATION OF SLURRY IN ROTATING KILN EQUIPPED w/SCRUBBERS.

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PAGE NO.	N.W. MATERIAL	NATIONAL DISPOSAL SITE	SCHEDULED Completion Date	ACTUAL Completion Date	RECOMMENDED TREATMENT
537	SILVER ACETYLIDE	YES	7	8	INTERIM DISPOSAL - DETONATION AT NATIONAL DISPOSAL SITE, OR IF TOO HAZARDOUS TO TRANSPORT, IN CLEARED AREA. RESEARCH ON DETOXIFICATION/DISPOSAL REQUIRED.
538	SILVER AZIDE	YES	7	8	IF SAFE, DISSOLVE OR CHEMICALLY WITH ELECTROLYSIS FOR RECOVERY OF SILVER. IF UNSAFE, DETONATION IN CLEARED AREA.
539	SILVER STYPHNATE		7		
540	SILVER TETRAZENE		7		
541	SMOKELESS GUN POWDER		7		
542	TETRAZENE ([illegible])	YES	7	8	IF SAFE, THERMAL DECOMPOSITION WITH STEAM. IF UNSAFE, DETONATION IN CLEARED AREA.
215	HYDROCYANIC ACID	NO	—	6 (p.218)	DILUTE: pH ADJUSTMENT/BLEACH OR HYPOCHLORITE ADDITION/pH ADJUSTMENT/DISCHARGE. CONCENTRATED: INCINERATION W/ALKALINE SCRUBBER.
218	HYDROGEN CYANIDE	NO	—	6 (p.218)	DILUTE: pH ADJUSTMENT/BLEACH OR HYPOCHLORITE ADDITION/pH ADJUSTMENT/DISCHARGE. CONCENTRATED: INCINERATION W/ALKALINE SCRUBBER.
385	SODIUM CHLORATE	NO	—	7 (p.[illegible])	REDUCTION; INCINERATION W/SCRUBBER
430	THALLIUM	NO	—	8	PRESENT METHOD ADEQUATE: STOCKPILING OF ZINC DROSS CONTAINING TRACE QTIES. OF THALLIUM; PRODUCTION OF THALLIUM FROM STOCKPILED ZINC DROSS
431	THALLIUM SULFATE	NO	—	8	PRESENT METHOD ADEQUATE: STOCKPILING OF ZINC DROSS CONTAINING TRACE QTIES. OF THALLIUM; PRODUCTION OF THALLIUM FROM STOCKPILED ZINC DROSS
122	COPPER SULFATE		7		

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NUCLEAR HAZARDOUS WASTE

* IN ALL CASES, ALT. LISTED IN RANK PREFERENCE

MATL. NO.	H.W. MATERIAL	NATIONAL GUIDANCE		ACTUAL COMPLETION DATE	RECOMMENDED* TREATMENT
	CESIUM-134	YES		7 (p 243)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	CESIUM-137 (BARIUM-137)	YES		7 (p 243)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGES, SPRAY SOLIDIFICATION/SALT BEDS
	PLUTONIUM-238	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	PLUTONIUM-239	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE, SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	PLUTONIUM-240	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	PLUTONIUM-241	YES		7 (p 293)	(RECOVERY OF UP TO 99.8% BY SOLVENT EXTRACTION PROCESS. REMAINING .2%: SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	AMERICIUM-241	YES		7 (p 280)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	AMERICIUM-243	YES		7 (p 280)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	CURIUM-242	YES		7 (p 282)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	CURIUM-244	YES		7 (p 282)	SPRAY SOLIDIFICATION/ENCAPSULATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/ENCAPSULATION/SALT BEDS
	RUTHENIUM-106 (RHODIUM-106)	YES		7 (p 320)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE: SPRAY SOLIDIFICATION/SALT BEDS
	CERIUM-144 (PRASEODYMIUM-144)	YES		7 (p 325)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	PROMETHIUM-147	YES		7 (p 333)	LOW LEVEL: RECOVERY/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	STRONTIUM-90 (YTTRIUM-90)	YES		7 (p 351)	LOW LEVEL: RECOVERY (SCAVENGING-PRECIPITATION ION EXCHANGE)/SOLIDIFICATION W/ASPHALT/LANDFILL. HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	ZIRCONIUM-95	YES		7 (p 357)	LOW LEVEL: RECOVERY (SCAVENGING-PRECIPITATION ION EXCHANGE)/SOLIDIFICATION W/ASPHALT/LANDFILL HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE; SPRAY SOLIDIFICATION/SALT BEDS
	NIOBIUM-95	YES		7 (p 355)	LOW LEVEL: RECOVERY (SCAVENGING-PRECIPITATION ION EXCHANGE)/SOLIDIFICATION W/ASPHALT/LANDFILL HIGH LEVEL: SPRAY SOLIDIFICATION/NEAR-SURFACE SOLID STORAGE, SPRAY SOLIDIFICATION/SALT BEDS
	CARBON-14	YES		8	SOLIDIFICATION W/ASPHALT, IF REQUIRED/LANDFILL
	COBALT-60	YES		8	SOLIDIFICATION W/ASPHALT, IF REQUIRED/LANDFILL
	IRIDIUM-192	YES		8	SOLIDIFICATION W/ASPHALT, IF REQUIRED/LANDFILL

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NUCLEAR HAZARDOUS WASTE

* IN ALL CASES, ARE LISTED IN RANK PREFERENCE

MATL. NO.	H. W. MATERIAL	NATIONAL CANDIDATE		ACTUAL COMPLETION DATE	RECOMMENDED * TREATMENT
	RADIUM-226	YES		8	NEAR-SURFACE SOLID STORAGE/SALT BEDS
	IODINE-129	YES		8	RECOVERY USING SILVER ZEOLITE/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	IODINE-131	YES		8	RECOVERY USING SILVER ZEOLITE/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	KRYPTON-85	YES		8	RECOVERY USING FLUOROCARBON SOLVENTS OR CRYOGENIC DISTILLATION/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	XENON-133	YES		8	RECOVERY USING FLUOROCARBON SOLVENTS OR CRYOGENIC DISTILLATION/NEAR-SURFACE SOLID STORAGE/SALT BEDS
	H^3-TRITIUM				
	SODIUM-14				
	TITANIUM-44				
	IRON-55				
	NICKEL-63				
	TANTALUM-182				

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ESTIMATED CHROMIUM WASTE GENERATION

Summarized in the following table are estimates of the chromates, dichromates and other chromium wastes generated in the United States. The waste is generally in dilute aqueous form but sometimes occurs in filter cakes and other solid wastes. Data is presented in terms of Bureau of Census regions previously discussed.

Most of the waste estimates in this table were taken from the Booz-Allen final report where their derivation is discussed. The remaining categories of wastes were estimated on a basis of contacts with industry representatives. The assumptions employed in generating the table are discussed below. Stored wastes are again from the military inventory. As a result of combining the survey results from Booz-Allen with those of TRW, a word of caution is expressed regarding the possibility of 1) the same sources having been included twice, or 2) a significant waste source having been omitted.

The amounts of waste from sodium dichromate production, as identified by Booz-Allen, are believed to be erroneous. The 300 million pounds of waste estimated by them is nearly equal to the total national production of sodium dichromate for 1971 (312 million pounds).[1506] Booz-Allen's waste factor of 1 pound waste per ton produced was therefore used to recalculate the total waste amounts. The distribution of the new estimate remains Booz-Allen's.

The metal finishing industry accounts for approximately thirty percent of the yearly national chromium chemical consumption. The waste factors in the industry are high where an estimated 85 percent occurs as waste.[1471,1472] This amounts to about eighty million pounds yearly. The distribution was made according to population which is believed to reflect metal finishing activities in the nation.

Ammonium chromate has very limited use in industry. The total yearly production is not believed to exceed 1 percent of the sodium chromate/

dichromate production, i.e. less than 1,500 tons.[2250] The only identified waste source is from the graphic arts industry as indicated on the table, but it is a small part of the yearly national consumption.[2235] Distribution is by population. Significant portions of the yearly production of ammonium chromate/dichromate are expected to occur as waste in other industries, but their source and amount is not currently known.

Potassium chromate/dichromate compounds are used in basically the same industries as the sodium compounds where special properties or conditions require the use of the potassium compound. Thus the sources and rate of waste production from consumption are assumed to be about the same as those of the sodium materials. Production of the potassium chromate/dichromate is estimated to be about 3 percent of sodium chromate/dichromate production (about 10 million pounds).[2250] Distribution is patterned after Booz-Allen's distribution of sodium chromate/dichromate in textiles, believed to be a major consumer. Part of chrome waste from the potassium compounds may be identified in Booz-Allen's textile waste estimate.

Chemical Profiles identifies 7 percent of the sodium dichromate production for use in anti-corrosion compounds (22 million pounds).[1506] It was assumed that the largest part of those compounds are used in cooling towers as sodium chromate. Consumption in the South is believed to be 50 percent of the total.[2262] The remainder is distributed in the U.S. according to population in the remaining regions.

REFERENCES

1471. Personal communication. James Zebers, Industrial Filter and Pump Co., to J. F. Clausen. TRW Systems, Mar. 21, 1972

1472. Personal communication. Alan Olsen, Parker Co., to J. F. Clausen, TRW Systems, Mar. 21, 1972.

1506. Sodium dichromate. In chemical profiles, New York, Schnell Publishing Co., 1969.

2235. Personal communication. R. McCann, Platemakers Education and Research Institute, to J. F. Clausen. TRW Systems, Mar. 17, 1972.

2250. Personal communication. R. Banner, Diamond Shamock Corporation, to J. F. Clausen, TRW Systems, Aug. 21, 1972.

2262. Personal communication. C. Hill, Humble Oil Co., to J. F. Clausen, TRW Systems, Aug. 24, 1972.

Material	Total	I	II
Wool Raw Waste $Na_2Cr_2O_7 + (NH_4)_2SO_4$	1.65×10^6	1×10^5	3.2×10^5
$Na_2Cr_2O_7$	2.47×10^6	1.5×10^5	5×10^5
Cotton Ray Waste Chromium	1.9×10^6	1.3×10^5	3.7×10^5
Sodium Dichromate Production Chromium Salts	1.5×10^5	1.8×10^4	3.2×10^4
Metal Finishing Mixed Chromates	8×10^7	4.6×10^6	1.5×10^7
Graphic Arts Photography Ammonium Chromate	4000	230	740
National Total Potassium Chromate/ Dichromate Estimate All Sources	1.0×10^7	1.9×10^6	7×10^5
Cooling Tower Blowdown Na_2CrO_4	2.2×10^7	9.2×10^5	2.9×10^6
Leather Tanning Chromic Sulfate	1.8×10^7	4.1×10^6	5.3×10^6
Stored on Okinawa Sodium Chromate			

A

CHROMIUM AND COMPOUNDS

II	III	IV	V	VI	VII	VIII	IX
	Annual Waste Production (#/yr)						
x 10^5	5.5×10^4	6×10^3	9.8×10^5	1.6×10^5	2×10^4	4×10^3	
10^5	8.5×10^4	1×10^4	1.47×10^6	2.4×10^5	3×10^4	6×10^3	
x 10^5	2.5×10^4	8.3×10^3	1.2×10^6	1.9×10^5	1.7×10^4	1.6×10^4	
x 10^4	2.5×10^3	3.2×10^4	2.5×10^4	1.5×10^4	1.8×10^4	--	5×10^3
x 10^7	1.6×10^7	6.4×10^6	1.2×10^7	5.0×10^6	7.6×10^6	3.3×10^6	1.0×10^7
	790	320	590	250	380	160	520
10^5	1.5×10^5	4×10^4	6×10^6	1×10^6	1×10^5	2×10^5	
x 10^6	3.1×10^6	1.3×10^6	1.1×10^7			6.6×10^5	
x 10^6	5.3×10^6	5.0×10^5	1.4×10^6	8×10^5	1×10^5	--	5×10^5
	Stored Wastes #						
							2765

B

VIII	IX	Explanation	Source
4×10^3		8 ppm in liquid	Booz-Allen
6×10^3		12 ppm in liquid	Booz-Allen
1.6×10^4		2 ppm in liquid	Booz-Allen
--	5×10^3	1#/ton product	Booz-Allen
3.3×10^6	1.0×10^7	Estimate 85 percent lost to waste stream.	0783, 1506, 1471, 1472
160	520	Gravurre leather press plate making	2235
2×10^5		Estimate 3 percent of sodium dichromate production--all industries	2250
6.6×10^5		7 percent of 156,000 tons of $NaCr_2O_7$ used in anti-corrosion	Chemical Profiles
--	5×10^5	9 lb/1000 lb hides	Booz-Allen
	2765	Military	2222